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A POPULAR GUIDE

TO THE

HEAVENS.

PREFACE.

The object of the present work is to provide a popular guide to the study of the sky by furnishing a summary of our present knowledge of the Solar system, a guide to the positions of the planets for the first half of the present century, a series of star maps, some examples of the finest achievements in the art of drawing and photographing celestial objects, and a list of interesting objects which may be observed with small telescopes.

In the text will be found a descriptive account of the plates, and of the methods of using the maps and tables. It is, however, desirable to draw attention in this place to certain characteristics of the work, and to make my acknowledgment to the friends who have kindly assisted me

In 1892 I edited an atlas of the celestial bodies which has long been out of print. Though this atlas bore my name yet as explained in the preface it was largely due to my friend Dr. Rambaut. The question of a new issue of the work having arisen, it was deemed better to recast the book completely, and the present volume is the result.

The star maps carefully drawn by Dr. Rambaut having been corrected for the changes obviously required by the lapse of 12 years have been retained, so have also the maps of the Moon, drawn by the late Mr. Elger.

But the advance of Astronomical portraiture has rendered it necessary to supersede most of the remaining plates by new material. This has involved so many changes in the text that the book is substantially a new one, and is now arranged in such a manner as may, I hope, entitle the book to be called a Popular Guide to the Heavens.

The map of Mars is reduced from the large map made by Mr A E. Douglass, published in Volume II. of the Annals of the Lowell Observatory.

The drawings of Jupiter on plate 9 have been copied from Dr. O. Lohse's observations, in the third volume of the *Astrophysiklische Observatorium* at Potsdam. The drawings of Jupiter's satellite are from a paper by Professor Barnard, published in the *Monthly Notices of the Royal Astronomical Society*. The drawing of Saturn, plate 10, by Professor Barnard, is reproduced from a drawing also published in the *Monthly Notices*.

The photograph of the great sun-spot of 1898 September is reproduced from a photograph taken at the Royal Observatory, Greenwich, for which I am indebted to the kindness of the Astronomer Royal.

The drawings of the Solar Prominences on plate 12 are from a paper by Herr Fenyi in the *Astrophysical Journal*; the picture of the Solar Prominence photographed by Professor Barnard is from the report of the Yerkes Observatory Eclipse Expedition to Wadesboro', U.S.A., published in the same journal.

The map of the paths of Solar Eclipses, 1901-1950, has been prepared from the series of maps in Dr. Oppolzer's great work, *Canon der Finsternisse*.

The photographs of typical Solar Coronae on plate 16 are selected from the series of Eclipse photographs brought together by the Royal Astronomical Society.

Plate 17, the drawing of Donati's Comet, by the late Professor Bond, is from the splendid volume of observations of that comet in the *Annals of the Harvard College Observatory*.

I am indebted to Professor Barnard for the use of the comet photographs in plate 18, which are selected from the series of his photographs published by the Royal Astronomical Society. I owe to him also the photograph of a region of the Milky Way in plate 81, taken from the same series.

For the permission to reproduce the two comet photographs of plate 19 I must thank the Astronomer Royal of England and the Astronomer Royal at the Cape respectively.

I am greatly indebted to Professor Hale, Director of the Yerkes Observatory of the University of Chicago, and to Mr. Ritchey, Astronomer at that observatory, who took the photographs, for permission to use the three photographs of the Moon, plates 20, 21, 22, the photographs of the nebulae in Orion and Andromeda, plates 73 and 17, and the drawings of the nebulae round Nova Persei. The photographs of the star and of the region in which it appeared I owe to Mr Stanley Williams, of Brighton.

My friend Mr W. E. Wilson kindly allows me to use the photographs of the Cluster in Hercules, and of the nebula in Cygnus, forming plate 75, which were taken by him at his observatory at Daramona, county Westmeath. To Professor Campbell, Director of the Lick Observatory, I owe permission to reproduce the photographs of the spiral nebula in Canes Venatici, the Ring nebula in Lyra, and the Dumb-bell nebula in Vulpecula, made with the Crossley Reflector by his lamented predecessor, Professor J. E. Keeler.

Plate 80, of the Pleiades Cluster, is taken from a photograph by the brothers Henry, published in a report of the Paris Observatory; and for the photograph of the nebulae in that cluster I am indebted to the late Dr. Isaac Roberts, of Crowborough, Sussex.

Plate 83, illustrating the adoption of Standard Time, and the line where the date changes, has been made from information kindly furnished by the Hydrographer to the Admiralty.

The work involved has been very onerous, and I could not have undertaken it had I not been so fortunate as to have had the aid of Mr. Arthur Hinks, M.A., Chief Assistant at the Cambridge Observatory. To Mr. Hinks I am indebted for the selection of the new plates, as well as for the preparation of the text which accompanies them. I would like to record my thanks to him for all his skill and zeal.

CAMBRIDGE,
November, 1904.

ROBERT S. BALL

Owing to this large displacement in the position of the Moon as seen from different parts of the Earth, a star which is occulted by the Moon at one place may be completely clear of it at another, and, similarly, while at one place a total eclipse of the Sun is seen, at another the eclipse may not even be partial

ANNUAL PARALLAX.

It is equally clear from the figure that a star will not be seen exactly in the same direction at different times of year. By far the greater number of stars are so far away that not even the displacement of the Earth by 186,000,000 miles produces any sensible effect. But upon a certain number of nearer stars the effect is just measurable They shift their positions relative to the more distant stars very slightly during the year ; and this effect is called Annual Parallax.

APPARENT DAILY ROTATION OF THE HEAVENS: RISING AND SETTING.

In consequence of the actual rotation of the Earth, from W to E., an observer upon it sees the heavens apparently rotating about an axis directed to the pole of the sky. Every celestial body therefore apparently describes once a day a circle round the pole. The pole is elevated above the horizon by an amount equal to the latitude of the observer Suppose this is 50°. A star nearer the pole than 50° describes the whole of its circle above the horizon ; it never sets, and is called circumpolar. A star further than 50° from the pole will not be circumpolar, part of its daily circle will be below the horizon, and a greater part the farther the star is from the pole, until for a star 180°—50°, *i e*, 130° from the pole, the whole circle is permanently below the horizon, and in lat. 50° N. this star will never rise at all.

The figure in Plate 2, "apparent diurnal paths of the Sun," illustrates this principle in the case of the Sun, and shows why the days are longer in summer than in winter · the sun is nearer the north pole of the sky in summer than in winter, for we have seen that the ecliptic cuts the equator at a considerable angle (23° 27′)

Tides.—The figure in the lower part of Plate 2 illustrates the fact that when a body like the Earth, covered with an ocean, is rotating, the attraction of the Sun or Moon produces disturbances in the level of the ocean, which are called tides. Though these protuberances are caused by the attraction of the tide producing body they are not necessarily, nor indeed generally, in line with it On an earth whose ocean is much broken up by continents the tidal waves are much broken up and disturbed, and the theory of the tides becomes exceedingly complex Owing to its relative nearness more than counter-balancing its smallness, the Moon is a much more efficient tide producing agent than the Sun.

The figure at the top of the Plate is to explain the expressions *spring* and *neap* tides. At New Moon and Full Moon the tides raised separately by the Sun and Moon conspire, and an exceptionally high tide is produced, which is called a *spring* tide. At first or last quarter of the Moon, the Sun tends to produce low water when and where the Moon tends to produce high water, and the result is a small or *neap* tide.

THE SIGNS OF THE ZODIAC.

The region of the heavens along the ecliptic, or the *zodiac*, was divided by the ancients into twelve parts, or *signs*, each 30° in length, which took their names from the principal

constellations along the zodiac. Thus, starting from the Vernal Equinox, the first sign was called Aries, the second Taurus, and so on. The gradual change in the position of the Equator and Equinox, due to precession, has thrown back the Equinox into the constellation Pisces, and displaced all the signs of the zodiac from the constellations whose names they bear Nevertheless the old names are retained, and the student must be warned against possible confusion. When the Almanac says "Sun enters Aries, spring commences," a reference to the star maps will show that the Sun is still in Pisces, and will be for a month We must distinguish, therefore, the names of the constellations from the same names applied to the signs of the zodiac

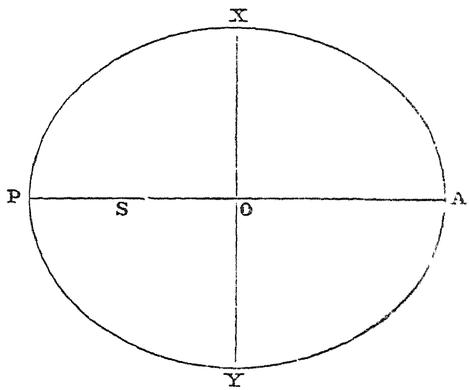
The Signs of the Zodiac, with their symbols, are given in the following table. Counting from the Vernal Equinox we have—

0° to 30°	..	0	♈	Aries	180° to 210°	.	VI	♎ Libra.
30° to 60°	...	I	♉	Taurus.	210° to 240°		VII	♏ Scorpio.
60° to 90°	...	II	♊	Gemini.	240° to 270		VIII	♐ Sagittarius
90° to 120°	...	III.	♋	Cancer.	270° to 300		IX	♑ Capricornus
20° to 150°	..	IV	♌	Leo.	300° to 330		X	♒ Aquarius.
50° to 180°		V.	♍	Virgo.	330° to 360°	..	XI	Pisces.

PLATE 3.

THE ORBITS OF THE INNER PLANETS.

In the attempt to represent the orbits of celestial bodies on maps or charts, it must always be remembered that, except in the case of orbits which happen to lie in the same plane it is impossible to depict on any drawing the veritable position of more than one. We are obliged to resort to some process of a more or less artificial character For instance, we take the plane of the Ecliptic, that is, the Earth's orbit, as the plane of the paper, and then we simply lay down on it the orbits of the other bodies, notwithstanding that their planes are inclined to the Ecliptic. The points in which the real orbit passes through the plane of representation are called the *Nodes*, the ascending node being that at which the planet passes from the southerly to the northerly side of the plane Each orbit may be conceived to be turned around its line of nodes till its plane coincides with the Ecliptic It is thus that Plate III is produced



THE ELLIPSE.

The path which every planet describes is an *ellipse*, and the Sun is situated in one of the two *foci* of the ellipse, S or H. The longest diameter of the ellipse, P A, which passes through the two foci, is called the *major axis*, the diameter X Y, at right angles to it, is the *minor axis*, and the two intersect in the centre, O, of the ellipse The points A and P are the *Apsides* of the ellipse. We will suppose the Sun is in the focus

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CHAPTER I.

Plates 1 & 2

THE CELESTIAL SPHERE, THE SEASONS, &c.

Our first plate is an attempt to represent in a diagram what cannot properly be figured, save in the imagination of the student, the relation of the terrestrial sphere to the celestial. The celestial sphere must be *imagined* of infinite diameter; in our figure it has to be *represented* as only twice the diameter of the orbit of the Earth about the Sun.

The centre of the Earth describes an ellipse, very nearly a circle, in a plane which passes through the centre of the Sun. If this plane is produced all ways to infinity it cuts the celestial sphere in a great circle—the Ecliptic. Could the Sun be viewed among the stars from the centre of the Earth, it would be seen to lie always upon this great circle

The axis of rotation of the Earth makes a constant angle with the plane of the ecliptic, and points constantly in the same direction. (We are neglecting here the very slow effects of precession) Consequently the plane of the Earth's equator, produced all ways to infinity, cuts the celestial sphere in a fixed great circle which is the celestial equator, and the axis of rotation of the Earth, similarly produced to infinity, cuts the celestial sphere in two points which are the poles of the celestial equator, more commonly called the poles of the sky.

It is now easy to see that at northern midwinter the north pole of the Earth is turned away from the Sun, which is at the winter solstice, the point where the ecliptic is farthest south of the celestial equator As spring advances, the Sun, apparently moving along the ecliptic, approaches the celestial equator, and enters it at the vernal equinox, otherwise known as the "first point of Aries." At northern midsummer the north pole of the Earth is turned towards the Sun, which then appears farthest north of the celestial equator, and thence forward begins to dip again towards the autumnal equinox.

It is found convenient to refer the places of all stars on the celestial sphere to the celestial pole and equator. Distance north or south of the equator is called north or south declination, and corresponds to north or south latitude of a place on Earth This provides for one co-ordinate. The other, called Right Ascension in the sky, corresponds to longitude on Earth, and as the longitude of a place is measured from a meridian on the Earth, which passes through the terrestrial poles and through an arbitrary point, namely Greenwich Observatory, so Right Ascension in the sky is measured from a meridian passing through the poles of the celestial equator and a point, the vernal equinox, the point where the ecliptic cuts the equator and the Sun crosses from south to north.

Right Ascension is commonly expressed in hours, minutes, and seconds of time, because it is measured as the time which elapses between the passage over the meridian of any place of

the first point of Aries and of the object whose position is to be defined. Declination is expressed in degrees of arc, because it is usually measured by graduated circles so divided on the instrument.

For further account of the subject of the measurement of positions on the celestial sphere, the student must be referred to the text books of spherical astronomy.

THE HORIZON AND THE ZENITH.

An observer upon the Earth is debarred by the Earth itself from seeing more than one half the sky at once. The plane which touches the Earth at the point where he stands, produced all ways to meet the celestial sphere, cuts it in the great circle which is his celestial horizon. When the observer is looking over the sea, his visible horizon is, owing to the spherical shape of the Earth, depressed below the above defined celestial horizon by an amount which depends on the height of the observer above sea level. This depression is called the "dip of the horizon," and must be taken into account when altitudes of a heavenly body are measured from the visible sea horizon. In other words, the celestial horizon is 90° from the zenith, the point vertically above the observer; the visible sea horizon is more than 90°, and the observer can by this amount see more than half the sky.

REFRACTION.

The effect of the layers of air through which light must pass on its way from a star to the observer upon the Earth is to raise the star apparently above its real position. The effect of refraction is sometimes very obvious when either the Sun or Moon is close to the horizon, in a flattening of the solar or lunar disc. The closer a body to the horizon, the more it is raised by refraction; the lower limb of the Sun is consequently raised more than the upper, with the result that the Sun appears no longer round, but flattened.

On the horizon a body is apparently raised 34′ of an arc.

At an	elevation	of 1°	"	"	24½′	"
"	"	3°	"	"	14½′	"
"	"	5°	"	"	10′	"
"	"	10°	"	"	5′	"
"	"	20°	"	"	2½′	"
"	"	30°	"	"	1½′	"
"	"	40°	"	"	1′	"

Above 40° of elevation the refraction is measured by seconds of arc alone, and becomes less and less till it vanishes at the zenith.

DIURNAL PARALLAX.

It is clear that when a celestial body is viewed from a point on the Earth's surface, it cannot appear precisely in the same direction as when it is viewed from the centre. The difference is named Diurnal Parallax. Owing to the small size of the Earth, and the vast distance of the stars, the Diurnal Parallax of stars is absolutely insensible. With the Sun and planets, however, the case is different. The nearer the body to the Earth, and the nearer to the horizon of the observer, the greater the effect. Upon the Moon the effect is quite large; when the Moon is just rising it appears lower among the stars than it would do from the centre of the Earth, by nearly a degree, or about two diameters of the Moon.

S in the figure, and that a planet is describing, under its attraction, the ellipse The ellipse is called its *orbit.* The point P, nearest to the Sun, is the *Perihelion* of the orbit, the point A, farthest away, is the *Aphelion* The half major axis, O P, which is also equal to the distance S X, is called the *mean distance.* The ratio of O S to O P is the *eccentricity* of the orbit, the smaller this ratio is, the more does the ellipse resemble a circle. The orbits of the more important planets all have small eccentricities.

It will be convenient to give here the symbols which are in use for the Sun, Moon, and Planets, and certain other signs used occasionally in this work.

Explanation of Astronomical Symbols and Abbreviations.

☉ The Sun	♂ Mars.	☌ Conjunction.
☾ The Moon	♃ Jupiter.	□ Quadrature.
☿ Mercury.	♄ Saturn.	☍ Opposition
♀ Venus	♅ Uranus.	☊ Ascending Node
⊕ or ♁ The Earth.	♆ Neptune	☋ Descending Node
h Hours.	° Degrees.	N. North. S. South
m Minutes of Time.	′ Minutes of Arc	
s Seconds of Time	″ Seconds of Arc	E. East W. West

The orbits of the planets Mercury, Venus, Earth, Eros, and Mars are represented in this Plate, and for illustrating the use of it we take the orbit of Mercury The point A is the Aphelion where the planet is most distant from the Sun The next point marked is the Ascending Node ☊, where the orbit comes through the plane of the paper, the inclination being 7° 0′, as given in the table in the upper right hand corner of the map P is the Perihelion, where Mercury is nearest the Sun. For a complete revolution this planet requires a period of 87 969 days. Similar remarks apply to the other orbits. Thus, for instance Mars, the outermost of the four planets shown in this figure, revolves in the period of 686 951 days Its Perihelion is marked P, and Aphelion A, the Ascending Node is ☊, and the inclination is 1° 51′. The inclinations of the cometary orbits are given in the right hand lower corner of the Plate The orbits of the three following comets are drawn, Biela's Comet, Comet I. 1866, and Comet III, 1862. These have been chosen because they possess the additional interest of being the paths of the three chief meteor swarms. The famous showers of "Leonids," which used to appear about November 13th, in magnificent displays every 33 years, move in the track of Comet I 1866 The "Andromedids," or meteors of November 27th, have the same orbit as Biela's Comet, and the "Perseids" pursue the course of Comet III. 1862 In the case of each of the cometary orbits the Descending Node has been marked on the Plate, as it is at this Node that the Earth meets the associated meteor swarm

The planet Eros is a recently discovered small planet, whose orbit is of a remarkable character. It is very eccentric, and considerably inclined to the ecliptic, and on favourable occasions the planet may be within about 13,000,000 miles of the Earth, nearer to us than any celestial body except our own Satellite.

PLATE 4

THE ORBITS OF THE OUTER PLANETS.

The innermost orbit on this Plate is that of Mars, for those belonging to planets still closer to the Sun would be too small to be shown in a figure of the scale necessary for the outer planets.

Next to Mars comes the zone of minor planets, of which more than 500 are now known, while some twenty or thirty new ones are discovered by photography yearly. Their orbits are tangled in a way impossible to represent otherwise than conventionally in a figure of small size. They exhibit great diversity of eccentricity and inclination to the ecliptic. And the task of keeping up the computation of the places of this fast growing family of tiny planets is becoming almost beyond reasonable possibility. In our figure the innermost represented is Medusa, with a period of 3·12 years; the outermost Hilda, with a period of 7·90. A later discovery, Adalberta, lies closer to the Sun than Medusa, with a period of 3·01 years; and Thule, with a period of 8·86 years, lies considerably farther out than Hilda.

Beyond the zone of minor planets lie the major planets Jupiter, Saturn, Uranus, and Neptune.

On this Plate are also represented the orbits of several interesting comets belonging to the Solar System. The Comet of Encke has the smallest orbit of any known comet, and it is especially interesting because of the somewhat irregular and unexplained acceleration to which it is subject. There is room on this Plate to show the orbit of Biela's Comet, part of which was shown on the preceding Plate.

Halley's Comet is the only periodic comet which makes a splendid appearance: the others are all small, many of them almost insignificant objects. But Halley's Comet on its last return had a nucleus as bright as a first magnitude star, and a tail twenty-five degrees long; and its next return in 1910 will be awaited with very great interest.

A portion of the orbit of the Comet of 1882 is shown on account of its remarkable nature. The comet passed so close to the Sun that it almost grazed, and it swung round 180° of its orbit in the space of three hours.

A remarkable relation, hitherto unexplained, connects the distances of the various planets from the Sun.

If we write down the series of numbers—

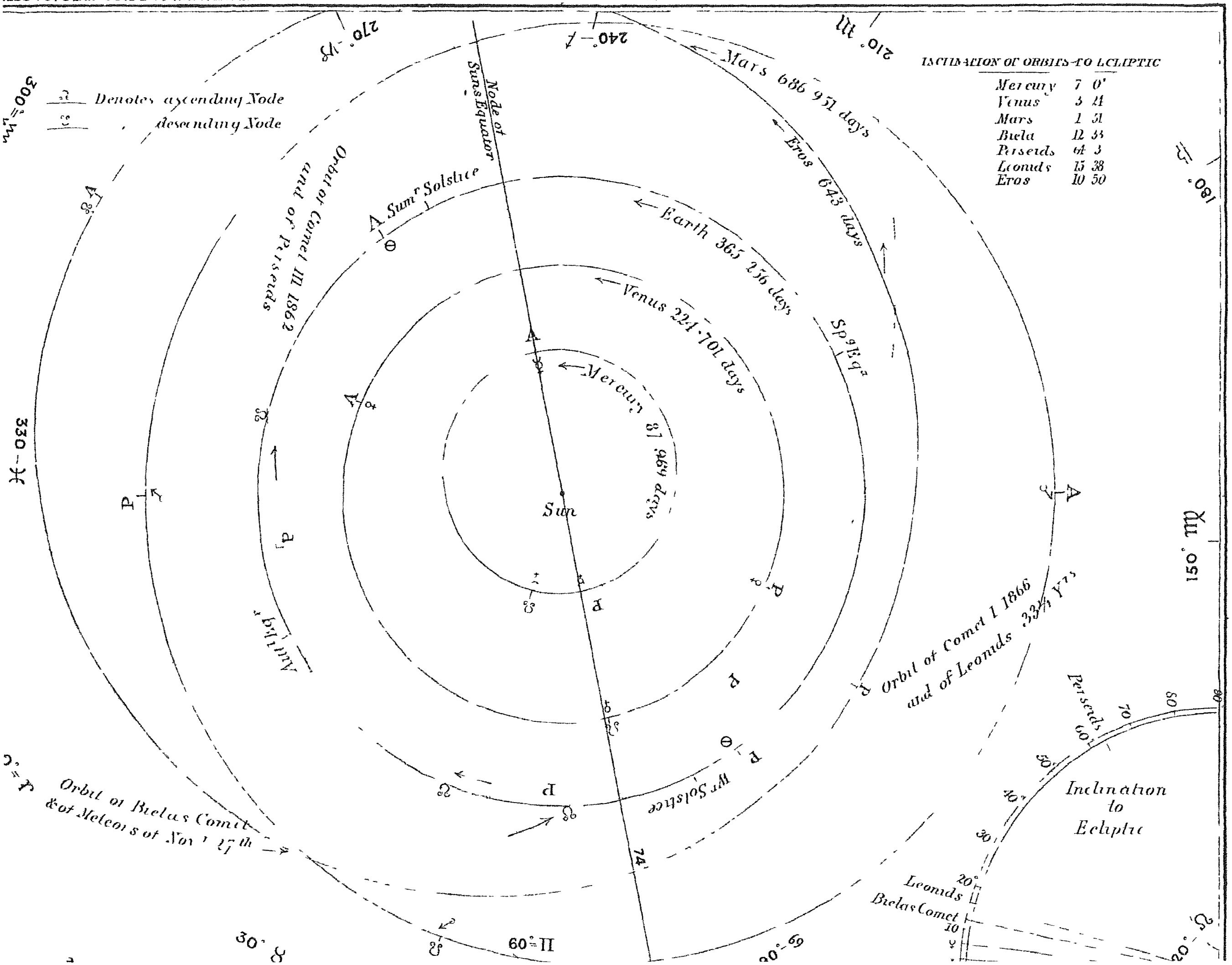
0 3 6 12 24 48 96 192 384,

and add 4 to each, we have

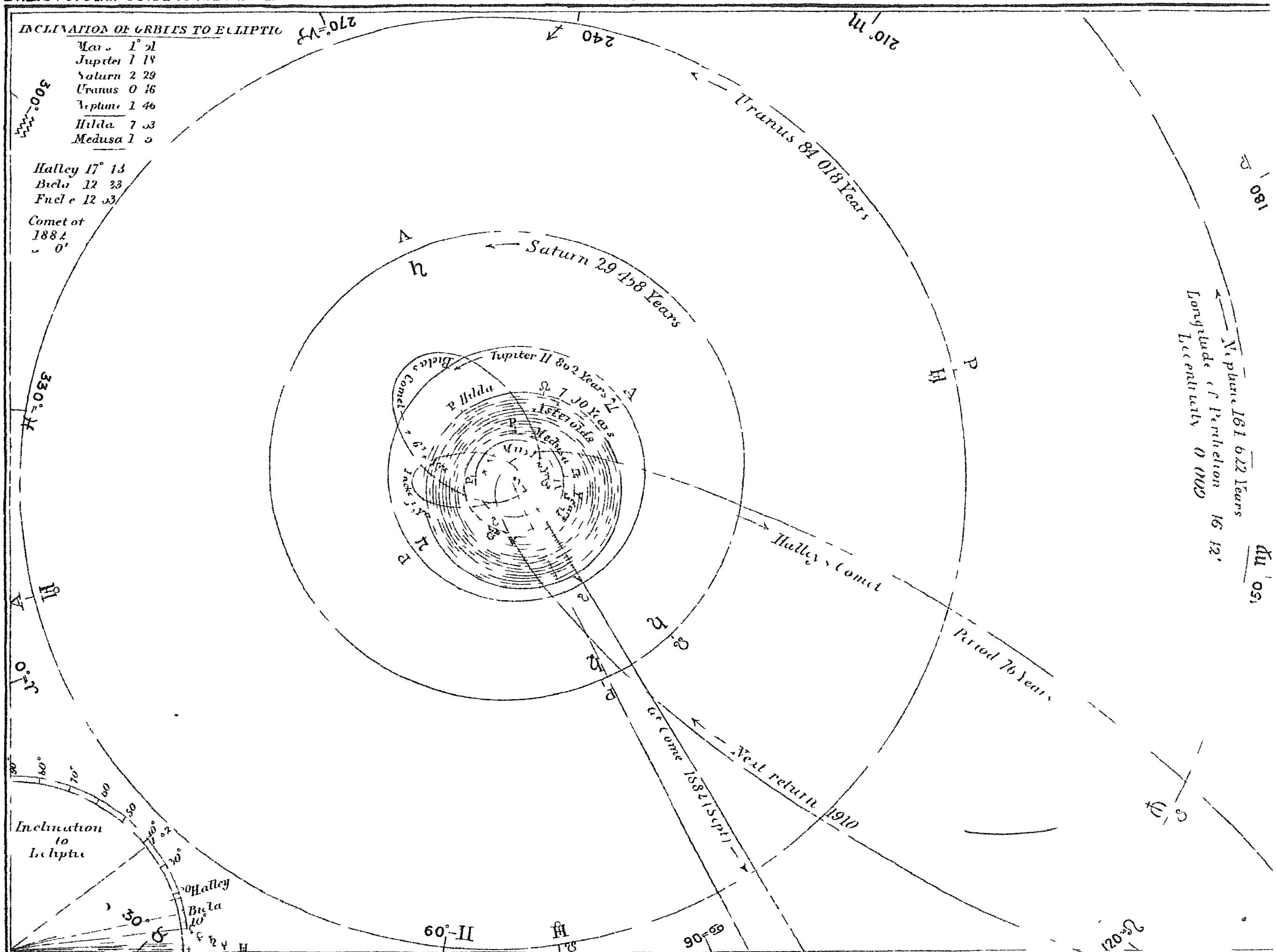
4 7 10 16 28 52 100 196 388.

The first four are very nearly in the proportion of the distances from the Sun of Mercury, Venus, the Earth, and Mars; 52 and 100 represent equally well the distances of Jupiter and Saturn; the intermediate No. 28, which stands for the average minor planet, actually suggested the search for them; when Uranus was discovered, it was found to fit 196; and when there was a suspicion of a planet beyond Uranus, it was assumed that its distance would be nearly represented by 388. But it is not; 300 is the real number, and here the rule, which is called Bode's law, breaks down completely.

THE INNER PLANETS



THE OUTER PLANETS



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CHAPTER II.

PLATE 5

THE SIZE OF THE PLANETS.

Plate 5 has been drawn to show the relation and actual sizes of the different planets and of the rings of Saturn The determination of the size of a planet in miles is by no means a simple matter Firstly, it is necessary to measure the angular size of the planets, as seen from the Earth, in seconds of arc, and this is affected by the phenomenon of irradiation by which a bright object against a dark background looks larger than it really is Also the planets Uranus and Neptune are so far away and look so small that it is hard to measure them, and it is still quite uncertain which is really the larger. We have therefore shown them equal. When the angular diameters at a given distance have been found, we next require a knowledge of the Solar Parallax, that is, of the angular radius of the Earth as seen from the Sun ; the adopted value of this quantity is 8″80. And, finally, we require the diameter of the Earth in miles , for this we adopt Col Clarke's latest value, 7926 6 miles

We can then calculate the diameters of the planets given below, and shown to scale upon the Plate The times of axial rotation and the inclination of the planets' equator to the Ecliptic are given when they are known

		Diameter in miles		Time of Rotation		Inclination of Equator to Ecliptic
Mercury		3,000	..	Unknown	..	Unknown
Venus .. .		7,700	..	Unknown	.	Unknown
Earth .. .		7,926	..	23^h 56^m 4^s	.	23° 27′
Mars . .		4,300	...	24 37 23	...	26 21
Jupiter	Equatorial	90,000	...	9 55		3 5
	Polar	84,000				
Saturn	Equatorial	76,000	...	10 14 0	..	28 10
	Polar	70,000				
Uranus		31,000	..	Unknown	..	Unknown
Neptune		31,000	...	Unknown	..	Unknown

Dimensions of Saturn's rings

Outer radius of outer ring	86,000 miles.
Inner radius of outer ring	75,000 ,,
Outer radius of inner ring	73,000 ,,
Inner radius of inner ring	55,000 ,,
Inner radius of dusky ring	44,000 ,,

All these dimensions are based upon a careful comparison of the most recent measures made with the great telescopes at Lick, Yerkes, Washington, and Greenwich Observatories. The time of rotation and position of the equator of Mercury, Venus, Uranus, and Neptune are unknown because of the want of definite markings on those planets. There is considerable reason to suppose that the periods of rotation of Mercury and Venus are the same as their periods of revolution round the Sun, namely 88 0 and 224 7 days. In that case they would always turn the same face towards the Sun. If we assume, which is probably true, that the satellites of Uranus and Neptune move nearly in the planes of the planets' equators, then we may add to the last column for those planets, 101° and 145°, the inclinations being given greater than 90° to conform to the fact that the satellites, unlike any other bodies in the Solar System, move in a retrograde direction

Recent measures have given the following diameters for the four principal minor planets :—

Ceres	..	...	...	480 miles
Pallas	...	...	.	300 „
Juno	...	...	...	120 „
Vesta	...	...	...	240 „

Plate 6.

PHASES OF THE PLANETS AND OF SATURN'S RINGS.

This Plate exhibits the appearances of the planets Mars, Venus, and Saturn when occupying different parts of their orbits. A reference to Plate 3 makes it clear that the distance between the Earth and Mars must vary considerably at different dates, according to the positions which the bodies occupy in their paths around the Sun. Of course, if the orbits were both circular, it is clear that the greatest possible separation between the two bodies would be attained at every *conjunction*, that is to say, whenever the Earth, Sun, and Planet are in a straight line (at least, in their projected orbits), the Earth and Planet being at opposite sides of the Sun The same diagram makes it plain that the least distance apart would occur at every *opposition*, that is, whenever the three bodies, as represented in their projected orbits, were in a straight line, with the Earth in the middle.

The eccentricity of the orbit of Mars considerably modifies the circumstances It will be seen, by referring to Plate 3, that an opposition occurring in the latter half of the year will generally be more favourable (*i e.*, bring the two bodies closer together) than one in the first half of the year, and that the most favourable opposition happens when the Earth and Planet are situated in about 333° longitude On the other hand, an opposition occurring in longitude 153° will be as unfavourable as possible The Earth's longitude on August 26th is 333°, and on February 22nd it is 153°, hence the most favourable opposition of Mars will occur on August 26th, and the closer to that date the opposition happens the better The most unsuitable oppositions are about February 22nd

The greatest distance at which the two planets can possibly be separated is attained when the Earth's longitude is 333°, and that of Mars 153°; that is to say, when *conjunction* occurs about August 26th

Figures 1, 4, and 5, in the upper part of the left-hand portion of Plate 6, show the relative apparent sizes of the planet—at most favourable opposition (August 26th), at least favourable opposition (February 22nd), and at its greatest possible distance These views illustrate the advantage of an opposition occurring somewhere near the end of August, when the appearance of the planet is to be studied.

When the lines from the Sun to the Earth and the Sun to the Planet are at right angles, the Planet is said to be in *quadrature* A very distinct phase is then perceptible in Mars, by which about a quarter of its diameter is cut off. The appearances of the planet at western and eastern quadrature, as shown in an inverting telescope, and the apparent size of the planet on the same scale as the other figures, is also given For the topography of the planet, the reader may refer to Plate 8. As to the times and seasons for observing Mars in its varying aspects, reference may be made to the Index to Planets, *see* pages 38 and 42.

Since the orbit of Venus lies inside that of the Earth, the appearances of this planet differ considerably from those of an exterior planet like Mars It is obvious that the nearest approach of the two bodies will occur at *inferior conjunction*, or when Venus and the Earth

are on the same side of the Sun; and that the greatest distance between them will occur at *superior conjunction*, or when the two bodies are at opposite sides of the Sun. It might, at first sight, therefore, be supposed that at inferior conjunction the planet would be seen best, being then apparently largest; and that it would be least favourably placed at superior conjunction. The relative apparent sizes of this planet *just before* inferior, and at superior, conjunction are shown in the lower part of the left-hand portion of this plate; but since, in the former configuration, the illuminated part of the globe is reduced to a very thin crescent, and since in both cases the planet is enveloped in the Sun's rays, in neither of these phases is it suitably situated for observation.

Venus attains its greatest brightness as an evening star about a month after its greatest elongation east. The greatest brightness of the same planet as a morning star precedes by about a month its greatest elongation west.

The second figure has been drawn to represent the size and shape of Venus when most brilliant. The third figure exhibits the appearance of Venus when situated at a distance of 40° from the Sun in the further part of its orbit. In this position it presents a *gibbous* form. It will be seen, however, that the diminution of light caused by its increased distance from the Earth, more than compensates for the larger proportion of the illuminated surface visible, so that, on the whole, the amount of light received from the planet is less than when it is in the position corresponding to Figure 2. In the Index to Planets, p 39, the method of finding the position of Venus for any date up to 1950 is explained.

For the general details of the planet Saturn reference may be made to Plate 11. In this place we discuss only the varying appearances of the rings. The right-hand portion of Plate 6 contains twelve figures depicting the different aspects which the ringed planet presents according to the position it happens to occupy in its orbit. In connection with the Table of Planetary Phenomena, p. 38, this plate will enable the reader to determine with considerable accuracy the appearance of the rings at any time. If the opposition of Saturn occurs in the middle of January in any year, it will be found that Fig. 1 represents the system. The rings are then opened nearly to their full extent, and the upper portion of the ball just extends beyond the outer margin of the rings. If the opposition occurs in February, the rings will be found to have closed up somewhat, and to appear as shown in Fig 2. If the opposition occurs in March, the rings will shrink almost to a straight line, as in Fig. 3. At oppositions occurring in April, May, and June, the appearances will be as in Figs 4, 5, and 6, the rings appearing the more open the more nearly the date of opposition approaches June. Figs 7—12, in a similar way, show the changes which this system will undergo at oppositions occurring in the latter six months of the year.

It must, of course, be understood that the appearance here depicted for any month will not recur every year in that month, but will only be seen in those years in which the opposition of the planet occurs during the month in question, and then only with accuracy at the date of opposition. But, as Saturn takes a period of no less than 29½ years to accomplish its revolution, the alteration in its appearance will vary very little for several months before and after opposition, so that the figure for any month may be taken to represent the appearance of the system during the year in which opposition occurs in that month. Thus, in the year 1921, the Table of Planetary Phenomena tells us that the opposition of Saturn takes place in March, whence we learn that during this year the rings will be almost edgewise towards us. Again, in the year 1928, opposition occurs in June, from which we infer that during that year the rings will be open to their fullest extent, and most favourably situated for observations.

These pictures have, as usual, been drawn to represent the planet as seen in an astronomical telescope, which always inverts the object, so that Figs. 3—8 exhibit the appearance of the system when the northern face of the ring is tilted towards us so as to become visible, while in Figs 1 and 2, and 9—12, it is the southern side of the rings which is seen.

To facilitate reference, a column has been added to the Table of Planetary Phenomena, p 38, to show which of the phases are presented in the corresponding opposition For example, if the opposition is in October, the column alluded to gives the number 10, which means that during the year in question the planet Saturn will present, when visible at all, a phase resembling that shown in Fig. 10 on Plate 8.

At the times when the ring is seen edgewise the sequence of appearances may be very complicated. The ring may become quite or very nearly invisible from any one of three causes;

(1.) The plane of the ring may pass through the Earth, in which case the ring is seen exactly edgewise And as the ring is very thin, its illuminated edge is not bright enough to be seen, and the ring disappears completely in all telescopes.

(2.) The plane of the ring may pass between the Earth and the Sun, in which case the Sun is shining on the opposite side of the ring to that which is presented, very obliquely, to the Earth; and in this case the ring is almost invisible, even in great telescopes

(3.) The plane of the ring may pass through the Sun, in which case neither side of the ring is effectively illuminated, and again it almost disappears

It is sometimes a matter of discussion how big a planet looks in a telescope of a given magnifying power. By means of this Plate the question may be answered. The Plate is drawn to such a scale that if it is placed ten feet from the eye the figures of the planetary discs subtend the same angle as the planets' images themselves, at the corresponding phases would do when seen in a telescope which gives a magnifying power of 80 diameters

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PLATE 7

SYSTEMS OF SATELLITES.

This Plate exhibits the relative dimensions of the orbits of the systems of satellites attending certain of the planets With the exception of the system surrounding Mars, which is on a scale twenty times as large as the rest, the orbits are all laid down on a uniform scale of half a million miles to the inch. The periods of revolution of the satellites around their primaries are also marked on the orbits approximately More complete numerical information than it has been found convenient to represent on the map is given in the following tables

THE SATELLITE OF THE EARTH THE MOON.
Mean distance from the centre of the Earth: 239,000 miles
Periodic time: 27 days, 7 hrs 43 mins 11 secs

THE SATELLITES OF MARS:	Mean distance from Centre of Planet			Periodic Time Days	hrs	mins	secs
Phobos	5,850 miles	...	...	0	7	39	14
Deimos	14,650 ,,	...	...	1	6	17	55
THE SATELLITES OF JUPITER:							
V. (Nameless) .	112,500 ,,	...	...	0	11	57	23
I. (Io)	261,000 ,,	...	...	1	18	27	34
II (Europa)	415,000 ,,	.	...	3	13	13	42
III. (Ganymede) ...	664,000 ,,	...	..	7	3	42	33
IV. (Callisto)... .	1,167,000 ,,	...	..	16	16	32	11

THE SATELLITES OF SATURN

Mimas	117,000 „	0	22	37	5
Enceladus	150,000 „	1	8	53	7
Tethys	186,000 „	1	21	18	26
Dione	238,000 „	2	17	41	10
Rhea	332,000 „	4	12	25	12
Titan	771,000 „	15	22	41	27
Hyperion	934,000 „	21	6	38	24
Iapetus	2,225,000 „	79	7	56	23

In July, 1904, Prof E C Pickering announced the confirmation of the discovery of a ninth satellite of Saturn, Phœbe, first found on photographs in 1899 Its period is about 1½ years, and its distance from Saturn about 8,000,000 miles

THE SATELLITES OF URANUS:

	Mean distance from Centre of Planet	Periodic Time. Days	hrs	mins	secs
Ariel	120,000 miles	2	12	29	21
Umbriel	167,000 „	4	3	27	37
Titania	273,000 „	8	16	56	30
Oberon	365,000 „	13	11	7	6

THE SATELLITE OF NEPTUNE:

(Nameless)	221,500 „	5	21	2	38

The satellites of Mars are a remarkable pair The inner, Phobos, is the only satellite that revolves faster than its primary rotates In consequence of this it must rise in the west, and set in the east The outer satellite, Deimos, revolves in a period so little greater than that of the planet that it goes through all its phases twice between the times of rising and setting.

The four well known satellites of Jupiter are almost always called by their numbers; their names, which have almost fallen into disuse, are therefore placed in brackets The fifth satellite, discovered by Barnard in 1892, still remains without a name

Recent measures have given the following values for the diameter of the four large satellites of Jupiter, and of Titan, the largest of the satellites of Saturn

I	2,500 miles.	III	3,600 miles
II.	2,200 „	IV.	3,300 „

Titan ... 2,900 miles.

But it is very probable that, on account of the effect of irradiation, these diameters may be several hundred miles too large

The diameters of the other satellites of our system are, for the present, beyond the reach of measurement If we measure the amount of light they reflect from the sun, and make some assumption as to their *albedo*, or light reflecting power, we can estimate roughly the probable diameters of the others. One finds that the Phobos and Deimos are probably about 10 and 30 miles in diameter, the fifth satellite of Jupiter, 100.

PLATE 8.

MAP OF MARS.

The selection for this work of a representation of the surface of the planet Mars is a matter of great difficulty Observers of Mars are divided into two camps—those who see the canals and those who do not. The former are in the strong position that they are perfectly

sure that they see what they represent in their drawings ; the latter declare that under the finest possible conditions of observation, and with the most perfect instruments, they can see nothing resembling the straight markings which are known as canals And further, they bring forward experiments which make it clear that irregularly disposed markings imperfectly seen, give the effect of straight streaks, by an optical illusion The interest which has been excited by the speculations based upon the drawings of these apparently artificial markings makes it impossible to present a chart of Mars in which the canals are omitted. We give, therefore, a reproduction of the chart of Mars made at the Lowell Observatory, Flagstaff, Arizona, by Mr. A. E. Douglass, from a study of all the drawings made there by various observers during the opposition of 1896-97. At the same time it is necessary to give the caution that some of the very best observers deny altogether the truth of this representation of the planet

Our difficulty is increased by the fact that there are two rival systems of nomenclature for the features of Mars—an earlier system in which the so-called lands and seas are named after modern Astronomers—Herschel, Leverrier, Dawes, &c , and a later, in which the names are taken from classical geography and mythology. The later system seems likely to prevail, and we have adopted it in the present work It is useless to give a catalogue of some 400 names of markings whose very existence is in dispute. We confine ourselves therefore to naming some of the more prominent features, to which a number is affixed in the plate

1 Fastigium Aryn
2 Margaritifer Sinus
3 Mare Erythraeum
4 Aurorae Sinus.
5 Ganges (Canal).
6. Lunae lacus
7. Solis lacus
8. Sirenius lacus
9 Mare Sirenum.
10 Eumenides (Canal).
11 Mare Cimmerium.
12. Charontis lacus
13. Mare Tyrrhenum.
14 Syrtis Minor
15 Syrtis Major
16. Cerberus (Canal)
17. Mare Icarium.
18 Edom promontorium.
19. Hellas
20 Ausonia.
21 Trivium Charontis
22 Orcus (Canal)
23. Pyriphlegethon.
24. Mare Chronium

It should be understood that in the unsteady air of England it is almost hopeless to expect to see many of the finer details. Not even in the most favourable climates are they to be seen always, or all at once. And much training of the eye is required before it is fit to decide for or against the existence of these details on the very verge of invisibility.

PLATE 9

JUPITER AND SATELLITE I.

Owing to the absence of permanent features on Jupiter it is not possible to give a map of the planet From year to year the position and breadth of the belts change, the tints of the surface change, and the shape and character of the spots change. Under these circumstances the best that can be done is to present drawings of the planet which are typical, yet possess features of more than average interest. We therefore select a set of drawings covering the period when the ‘ great red spot ” was most conspicuous. It was first seen in July 1878, and

in the following year it was the most conspicuous feature on the planet (Figs. 4, 5, 6) In 1880 and 1881 it changed but little (Figs 7, 8, 9, 12), but after that began to fade ; and at the present time it is visible only as an indentation or scar on the southern equatorial belt. It was evident almost from the first that its period of rotation was not the same as that of the average spot in the belt near it These gained 22 secs. upon it at each rotation And though the spot is more or less permanent its own time of rotation has changed by 6ˢ, and for these facts no satisfactory theory has been suggested

The satellites of Jupiter were the first discoveries made with the telescope, and they remain the most beautiful and interesting objects that a small telescope can show. Their eclipses and occultations and transits over the planet's disc are predicted in the *Nautical Almanac* year by year, to which reference may be made also for the configuration of the satellites each night

With a very powerful telescope the phenomenon of the transit of satellite I. is very curiously varied The figures are from drawings made by Prof. Barnard at the Lick Observatory It had been noticed that when Satellite I. was crossing the disc of the planet, is sometimes appeared double and sometimes very elongated The drawings supply the explanation The satellite, not unlike its primary, has a bright equatorial region and darker poles When it is projected upon a dark belt of a planet the former alone is seen ; when upon a bright belt the latter The drawing made November 19, 1893, shows the phenomena most completely The satellite was seen against the boundary separating a bright from a dark belt , and it was also partly superposed upon its own shadow. It is scarcely necessary to add that, since the whole apparent diameter of the satellite is little more than a second of arc, it requires the finest telescope and skill to see what is here shown.

PLATE 10.

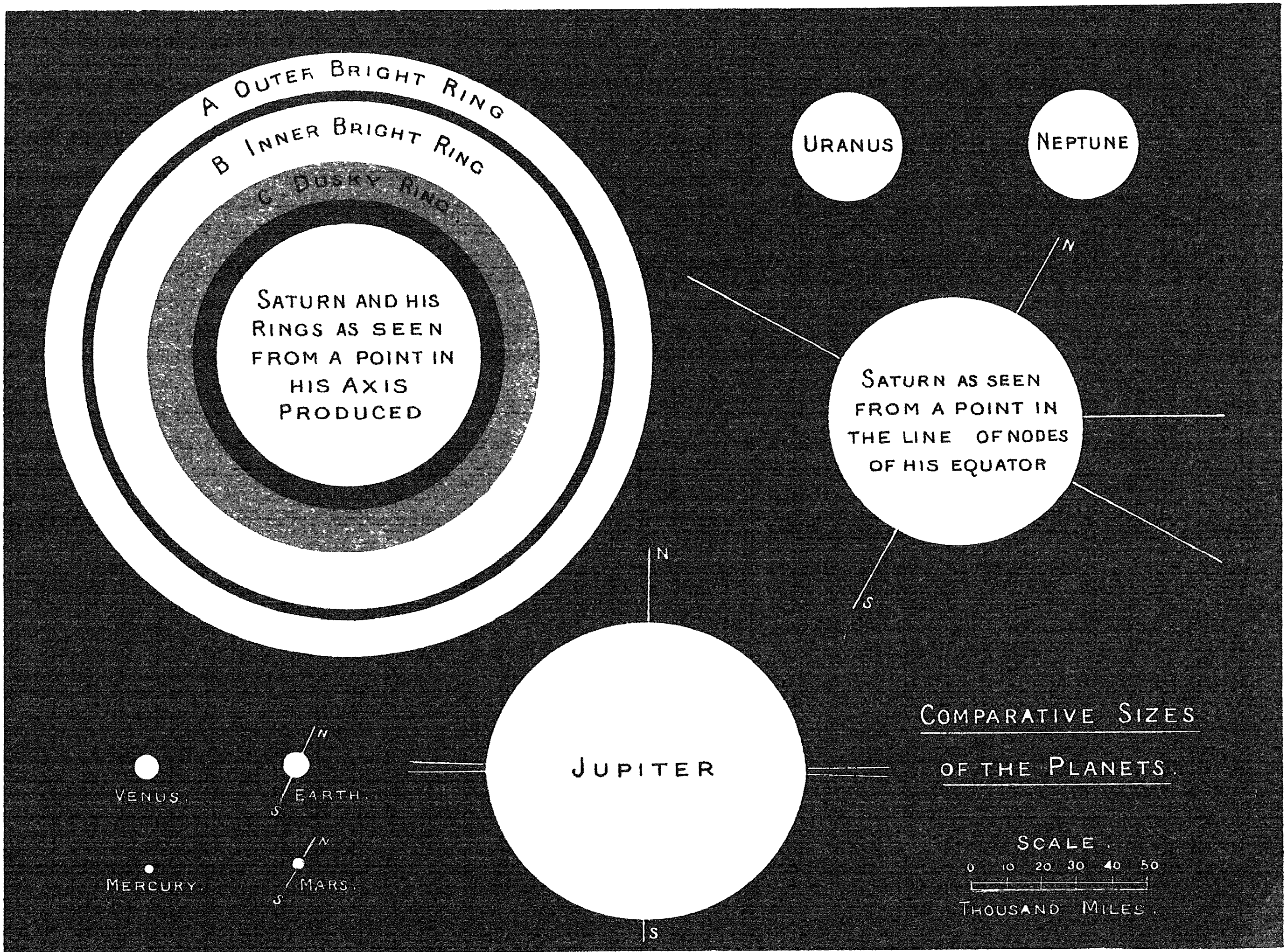
SATURN.

We are indebted again to Professor Barnard and the Lick telescope for the drawing which has been chosen to illustrate the appearance of the planet Saturn Although spots are sometimes seen upon the planet, they are uncommon, and the surface markings are usually no more than a few vague dusky belts , the interest lies in the rings.

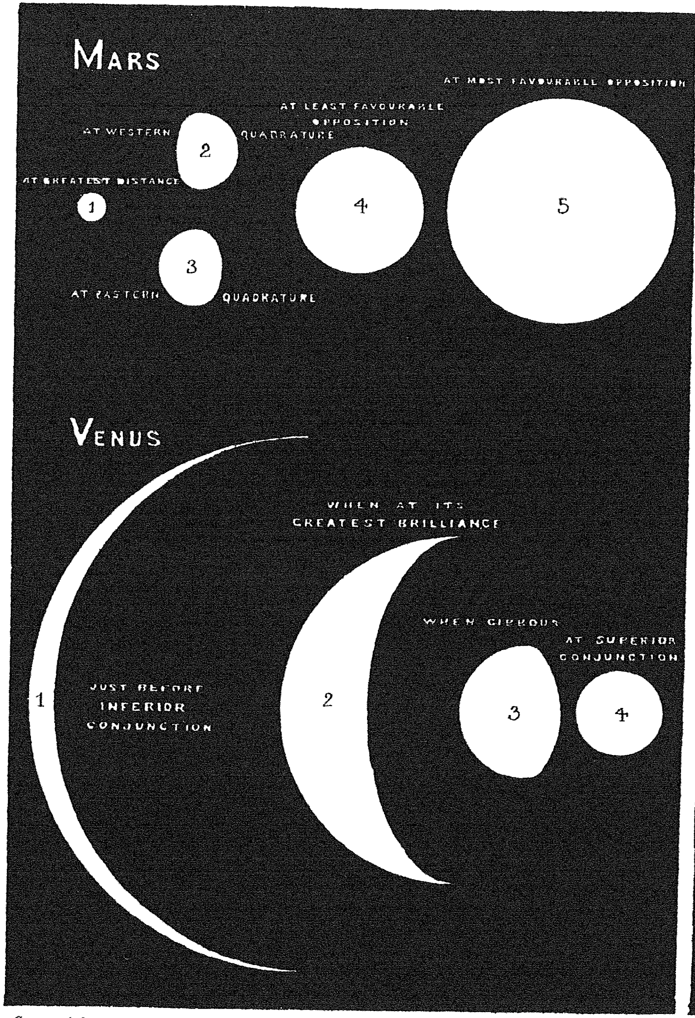
In looking at the plate we must imagine the sun behind us and a little to the left. The shadow of the ball is seen upon the rings (at the right hand limb) and the shadow of the rings is seen upon the ball (above). The Cassini division was plainly visible all round, but the Encke division in the outer ring was not visible at the time ; it seems to be a thin place in the ring rather than an actual division. The dusky, or crape ring, showed steely blue against the sky, and at its inner edge was so transparent that the planet could be seen through it. Where it joins the inner ring there is no division, but the two rings merge rapidly the one into the other The brightest part of the whole is the outer edge of the inner bright ring.

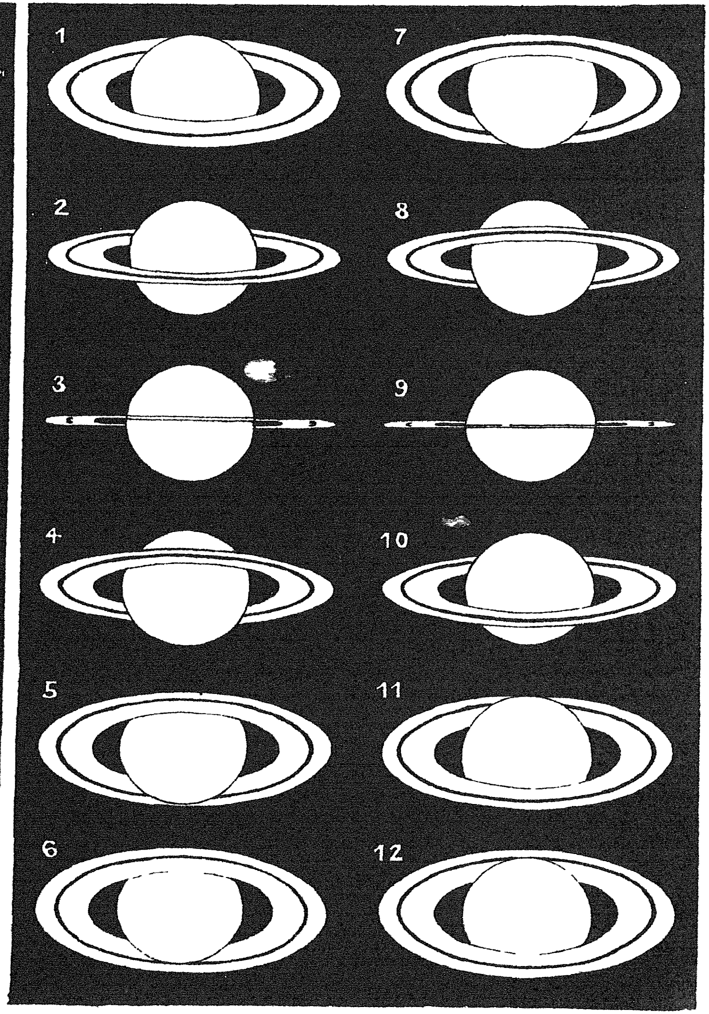
Since this drawing was made the rings have opened out to their fullest extent, and are now (1903) closing in again as the planet approaches the interesting point in its orbit where the rings are seen edgewise.

THE SIZE OF THE PLANETS



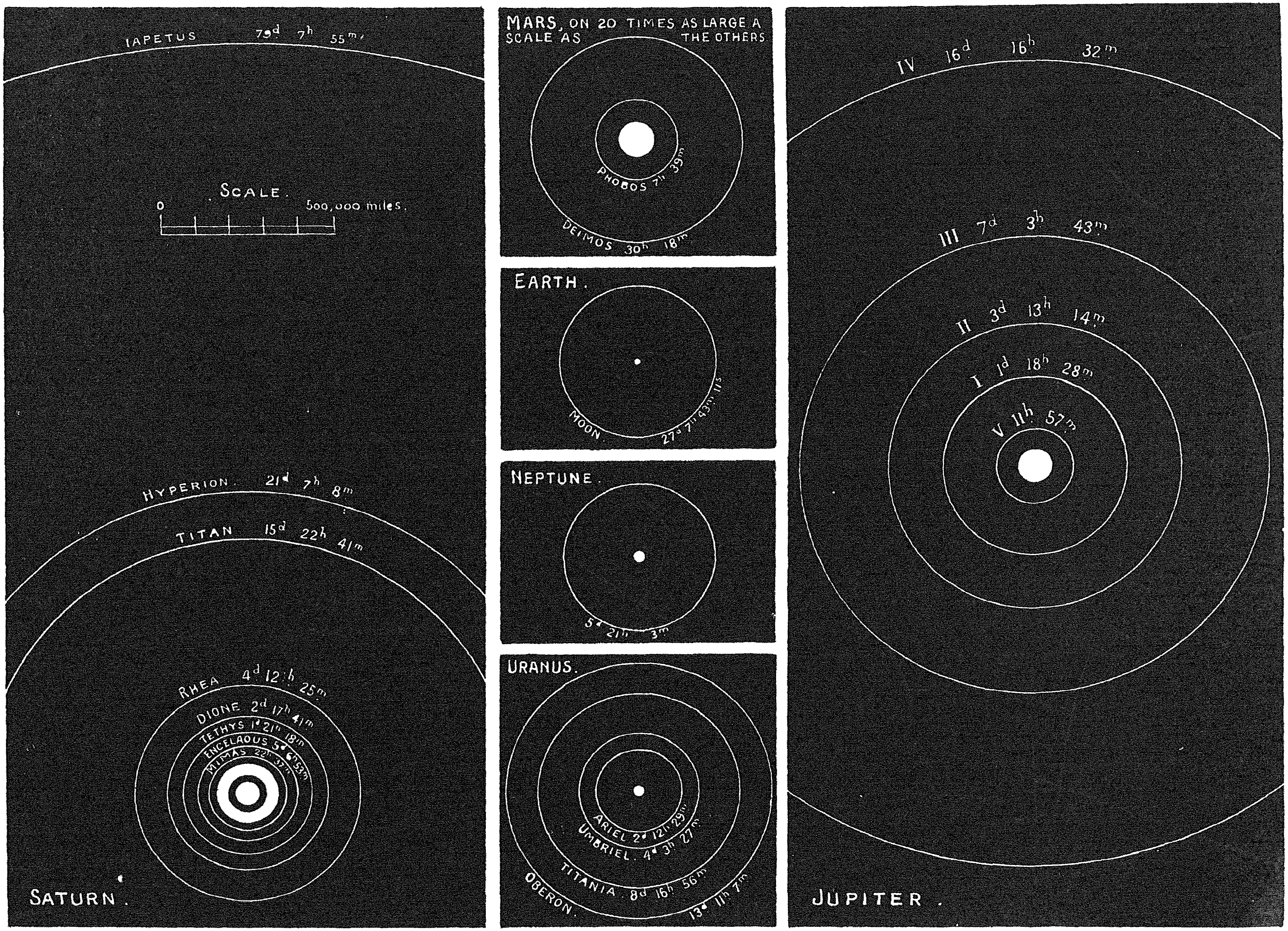
PHASES OF THE PLANETS & OF THE RINGS OF SATURN. Plate 6





The London Geographical Institute

SYSTEMS OF SATELLITES.



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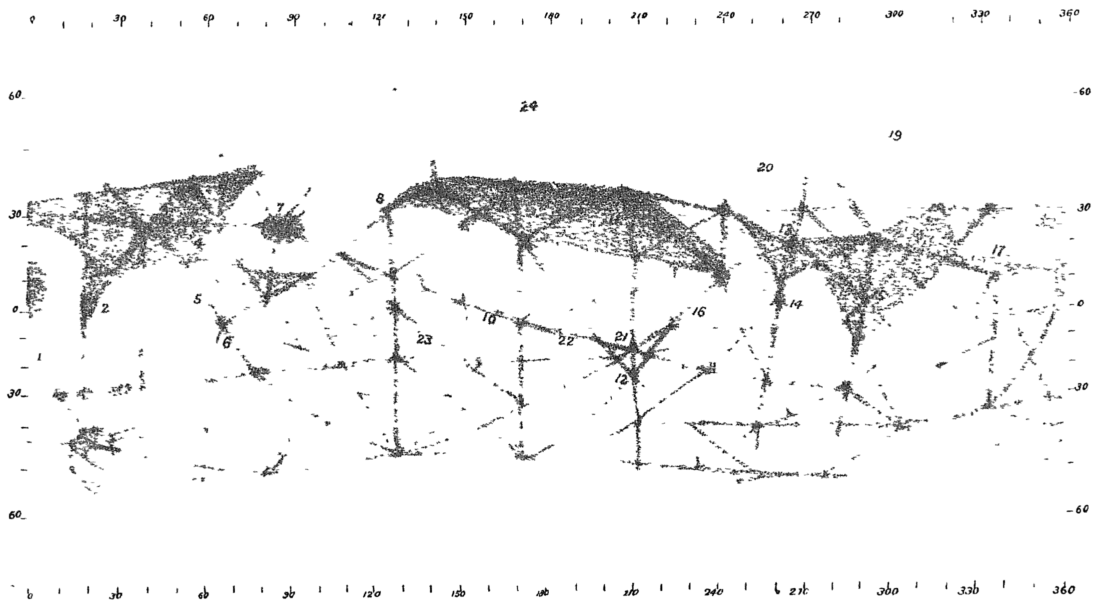
MAP OF MARS, 1896-97.



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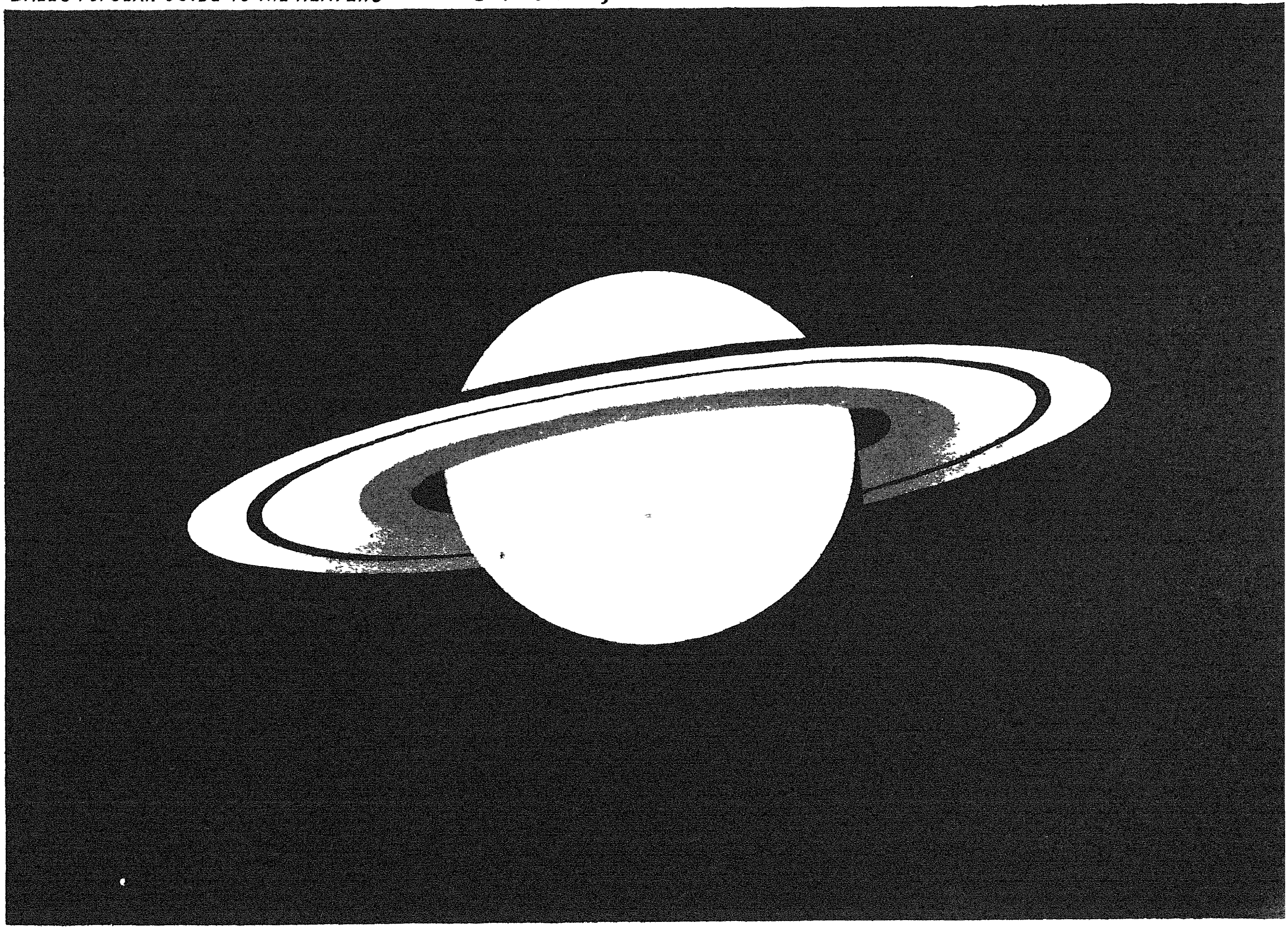
from Map made by A. E. Douglass

The London Geographical Inst.

SATURN, JULY 2ND 1894.



George Ph Lp & S n I

CHAPTER III.

PLATES 11 & 12

THE SUN.

A very important branch of the work of the Royal Observatory, Greenwich, is the daily record, by photography, of the number and size of the spots which appear upon the Sun's surface To fill the gaps caused by cloudy weather in England photographs are taken also in India and Mauritius, and are sent home to Greenwich, so that there are very few days in the year for which there is no record. The purpose of this continuous survey of the Sun is to determine the laws which govern the changes in the area and position of the spots It is well-known that the number of spots reaches a maximum about every eleven years ; that at the beginning of each new period the spots are found in higher solar latitudes than at the end ; and that there is an unmistakable, but unexplained, connection between the frequency of Sun spots, of displays of the Aurora Borealis, and of terrestrial magnetic storms. One of the finest Sun-spot photographs ever taken at Greenwich is reproduced, by permission of the Astronomer Royal, in Plate 11 The structure of the group is very complex Every large spot is accompanied by a crowd of smaller spots, which change comparatively quickly. A large regular spot consists of two well-defined portions—the black central *umbra* and the surrounding grey *penumbra*. In the latter, the bright granules which form the *photosphere* of the Sun are elongated and drawn in towards the centre of the spot, making the structure of the photosphere somewhat like thatch. Very frequently bright bridges are thrown across from one side to the other, and this is generally the prelude to the filling up of the spot

Sun spots are the seat of tremendous activity in the layers of glowing gas lying above the photosphere. The most remarkable of the gaseous *prominences*, which stand out above the limb of the Sun when it is totally eclipsed, are almost always associated with spots lying beneath them. The lower part of Plate 12 is the reproduction of a photograph taken by Prof. Barnard and Mr Ritchey during the total eclipse of 1900—May 28th. These prominences are outbursts of hydrogen, calcium, and occasionally of other metallic vapours, which are often thrown up from the surface of the Sun with enormous velocities. The prominences are conspicuously seen during a total eclipse because the glare in our atmosphere, which ordinarily surrounds the Sun, is then for the moment removed The application of a spectroscopic method now enables us to abolish the effect of this glare at any time, and it is possible to make a daily record of the prominences

The upper part of Plate 12 is a reproduction of a set of drawings of a single prominence made in this manner by Herr Fenyi, at Kalocsa in Hungary, on 1895, July 15 His description is as follows At 7.10 a.m., Greenwich M T., a very delicately formed prominence stood precisely on the place where a considerable group of Sun spots was passing out of sight round the limb (Fig. 1). When Fig. 2 was drawn at 7.40, the form of the prominence was

changing with extraordinary rapidity. Determinations of the velocity with which parts of the prominence were moving gave results up to 500 miles per second Fig. 3 was drawn at 8.7; Fig 4 at 8.30, when the prominence had reached its greatest height of about 100,000 miles At 8 45 its shape had changed very much, and at 9.35, when Fig. 6 was drawn, the great protuberances had completely gone, and the prominence had returned to nearly its appearance of 2½ hours before.

PLATE 13.

PATHS OF SPOTS ACROSS THE SUN'S DISC

By the rotation of the Sun on its axis, the spots appear to be carried across the disc, along paths parallel to its equator.

The axis, around which the Sun rotates, is inclined to the ecliptic at an angle of 82° 45′. The inclination of the Sun's equatorial plane to the ecliptic is therefore 7° 15′

The ascending node of the Sun's equator is the point at which a spot on the equator of the Sun would be carried by the Sun's rotation from the southern to the northern side of the ecliptic, and the longitude of the node is the angle which the direction of this point makes with the direction of the *First Point of Aries* as seen from the Sun's centre. The actual value of the longitude of the ascending node is 74°. Its position is marked on Plate 2

Plate 13 shows the paths along which the spots appear to travel at different dates They are here represented as actually on the face of the Sun, and not as seen through the inverting telescope that the astronomer ordinarily uses.

On December 6th, the Earth is in the line of nodes, and, consequently, in the plane of the Sun's equator, and the paths pursued by the spots will therefore appear projected into straight lines Again, on June 5th, when the Earth is in the opposite point of its orbit, it will be again in the plane of the Sun's equator, and the paths of the spots will again appear projected into straight lines.

On March 4th, the Earth, being then 90° from the node, will be depressed below the Sun's equator by an angle of 7° 15′, and the paths of the spots will appear as ellipses of considerable curvature, with their convexities towards the north; while, on September 6th, from the opposite point of the orbit, the same curves will reappear, only that they will now be convex towards the south From March till June, and from September till December, the curvature is decreasing, while in the intervening periods corresponding changes take place in the opposite direction We may describe these changes in a somewhat different way by saying that on June 5th and December 6th both poles of the Sun are visible just on the edge of its disc, from June to December the north pole only is visible; and from December to June the south pole only can be seen

By the "position angle of the Sun's axis," is meant the angle which the projection of the northern half of the Sun's axis on its apparent disc makes with the meridian passing through the Sun's centre, reckoned positive towards the eastern, and negative towards the western side of the disc. If the observation is made at noon, it is the angle which the direction of the axis makes with the vertical, when the image is viewed projected on a sheet of paper placed behind the eyepiece of an inverting telescope. If the observer's back be turned towards the

Sun, the position angle will be positive when the upper half of the axis leans towards the right, and negative when it leans towards the left. On such a projection the cardinal points, N, S, E., W, lie just as they do in an ordinary terrestrial atlas On January 5th and July 6th, the position angle of the Sun's axis is Zero ; from July 6th it gradually increases in a positive direction until it reaches its greatest value, viz + 26° 20', on October 10th. From this date it gradually diminishes till January 5th, after which it becomes negative, reaching its greatest negative value, viz. : – 26° 20', on April 5th, and returning once more to Zero on July 6th.

PLATE 14

PHASES OF THE MOON: LUNAR AND SOLAR ECLIPSES.

Phases of the Moon—The hemisphere of the Moon that is turned towards the Sun is, of course, brilliantly lighted, the other hemisphere is dark As the Moon moves in its orbit round the Earth, the illuminated side is turned towards us in varying proportions, and the relation between the phases thus produced and the relative positions of Sun, Earth, and Moon is shown in the upper part of the plate

When the Moon is but a few days old, and appears as a thin crescent, it frequently happens that part of the Moon which is not lit directly by the Sun is seen faintly shining by the reflected "Earth-light," an appearance known as "the old Moon in the new Moon's arms"

Eclipses of the Moon.—The Sun throws behind the Earth a dark cone of shadow, which reaches a long way beyond the path of the Moon, and if it had happened that the path of the Moon lay precisely in the ecliptic, then, at every full Moon, she would pass through this shadow, and be totally eclipsed Since, however, the Moon's path makes a small angle with the ecliptic, she usually passes a little above or below the cone of shadow, and escapes eclipse But, from time to time, the Moon is crossing the ecliptic just about the time of full, and then a partial or total eclipse occurs, and is visible over the whole of that hemisphere of the Earth which is at the moment turned away from the Sun and towards the Moon. It follows that a total eclipse of the Moon—being visible, whenever it occurs, over at least half the Earth—is not a very uncommon spectacle.

Eclipses of the Sun—The Sun also throws behind the Moon a dark cone of shadow ; smaller than that thrown behind the Earth, because the Moon is smaller, but just long enough, on the average, to reach the Earth When the Moon is nearest the Earth, the cone of shadow may cover a space about 170 miles broad ; and, with the motion of the Moon, this shadow-patch sweeps quickly over the Earth. Within the shadow-belt, for a few minutes, the Sun is just a little more than completely obscured by the Moon, and there is a *total eclipse* of the Sun. When the Moon is farthest from the Earth, the shadow-cone does not reach the Earth, so that from no point can the Sun be seen completely obscured ; at best, there is a ring of Sun showing all round the Moon, and the eclipse is *annular*, At points lying outside the belt of totality, or of annularity, the Sun may be partially obscured by the Moon, and there is a *partial* eclipse. But the limits within which any eclipse at all is visible are far within the boundary of the whole hemisphere of the Earth which is turned towards the Sun, and consequently eclipses of the Sun of any kind are much more rarely seen at any one place than are eclipses of the Moon.

PLATE 15.

PATHS OF TOTAL ECLIPSES OF THE SUN, 1901–1950

In his great work, "Canon der Finsternisse," Prof. Oppolzer has given maps of the paths of the Moon's shadow over the surface of the Earth for all the total and annular eclipses of the Sun between the years 1207 B.C. and 2162 A.D. From this work Plate 15 has been prepared, showing the tracks of the *total* eclipses visible between 1901 and 1950 A.D. At the western end of each line the eclipse begins at sunrise; the point in the middle of each line, where the eclipse is at noon, is marked by a circle, and at the eastern end of the line the eclipse begins at sunset.

An examination of these curves will show in a striking way the repetition of eclipses in a period of about eighteen years and eleven days, which period, known to the Chaldeans, is called the *Saros*. Take, as an example, the Great Eclipse of 1901—May 18th, occuring at mid-day in long 97° E., lat 2° 5′. We have on our Plate three eclipses of this series, viz. —

			Lat	Long
1901—May 18	.	Eclipse at mid-day in	97° E	2° S
1919— „ 29		„ „	18 W	4 N
1937—June 8		„ „	131 W	10 N.

And later eclipses of the same series are —

1955—June 20	...	Eclipse at mid-day in	117° E	15° N.
1973— „ 30		„ „	6 W	19 N
1991—July 11		„ „	105 W	22 N.

The centre of the track of the eclipse is gradually moving north, and is at each repetition about seven hours, or 105°, farther west in longitude.

Let us take as another example the history of the eclipse which will be total in England in June, 1927. The dates of the three eclipses of this series represented on our Plate are —

1909—June 17 | 1927—June 29. | 1945—July 9.

The first begins in Siberia, crosses close to the North Pole, and runs down the west coast of Greenland. The second begins in the Atlantic, south-west of Ireland, crosses Great Britain, runs up Norway, through the Arctic Ocean, and ends south of Behring Straits. The third begins in Canada, crosses Greenland and northern Norway, and ends in Central Asia.

It will be seen that the circumstances of the path of an eclipse are very complex, especially when its centre is in high latitudes, and the reason for this may be readily understood if one looks at a globe, tilted with respect to the Sun, according to the time of the year of the eclipse, and considers how the shadow of a body, the Moon, passing between the Sun and the globe would cut across the tilted lines of latitude and longitude.

PLATE 16.

TYPICAL SOLAR CORONAE.

By far the most beautiful feature of the totally-eclipsed Sun is the *corona* of pale white light which flashes out as soon as the dazzling photosphere is completely covered by the

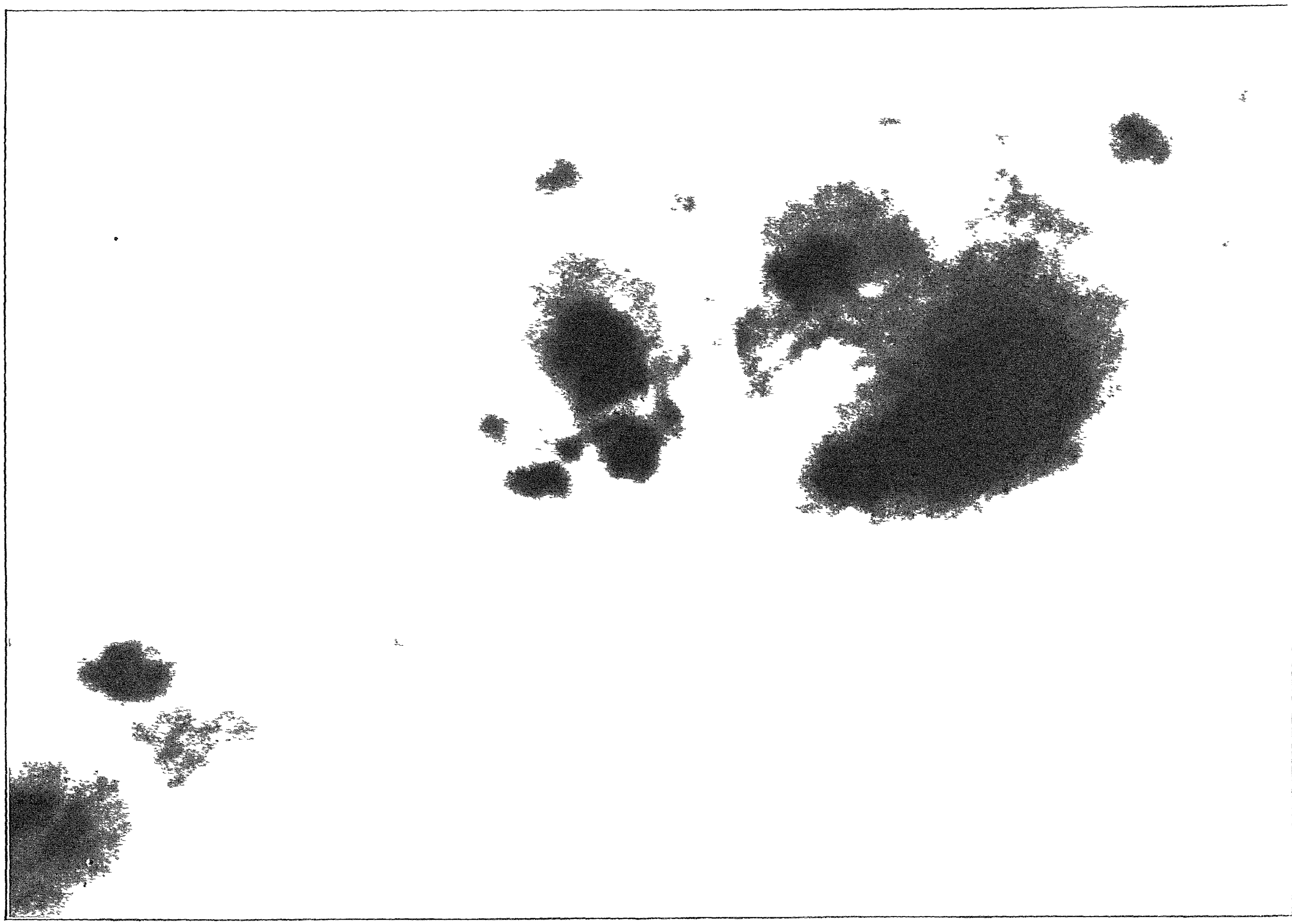
Moon In the three or four minutes which is the average duration of totality it is almost impossible to draw or describe the very complex structure of this appendage of the Sun. But, for the last twenty-five or thirty years, almost every eclipse has been successfully photographed. A reference to Plate 15 will show the arduous character of the journeys which are often involved in eclipse-observation The six photographs which are reproduced in Plate 16 were taken as follows :

1.	1871	Dec 12.	H. Davis	Baikul, India.
2.	1882	May 17.	Abney and Schuster	Egypt
3.	1893.	April 16.	J. Kearney	Fundium, W. Africa.
4	1878.	July 29.	W. Harkness.	Wyoming.
5	1889.	Jan. 1.	W H. Pickering	California.
6	1900.	May 28.	E. E. Barnard.	Wadesborough, N. Carolina.

The photographs have been arranged in two sets, in which it will be seen that the corona is of distinctly different types In the first set—1871, 1882, 1893—the corona is fairly equally distributed right round the limb of the Sun , in the second set—1878, 1889, 1900—the corona has large equatorial extensions, and at the poles it is broken up into short, distinct streamers Further, it will be noticed that the interval between successive photographs in each set is about eleven years—the sun-spot period , the first set fall near the times of sun-spot maximum, the second near times of sun-spot minimum.

Not very much is known of the nature of the corona. The streamers shine largely, if not entirely, by reflected light from the Sun, and must, therefore, be composed of small particles Diffused amongst them, but probably not sharing in their radial structure, is an unknown gas—called, for convenience, "coronium" That some of the detailed structure of the corona is connected with underlying sun-spots and prominences is certain But the most significant fact is the evident dependence of the forces which determine the form of the corona upon the same cause, whatever it may be, which produces the periodicity of the sun-spots, disturbance of the magnet, and aurorae.

The corona and prominences alike are ordinarily invisible to us, because they are not nearly so bright as the flare in our atmosphere which seems to surround the Sun. The spectroscope has made it possible to observe the prominences continuously ; but, up to the present, no method has been found of viewing the corona except during the rare minutes of a total eclipse.



A GREAT SUNSPOT, 1898, Sept 11th

ROYAL OBSERVATORY GREENWICH

it is not in session in the session immediately following, for a total preriod of fourteen days which may be comprised in one session or in two successive sessions, and if, before the expiration of the session in which it is so laid or the session immediately following, both Houses agree in making any modification in the rule or in the annulment of the rule, the rule shall , from the date on which the modification or annulment is notified in the *Andhra Pradesh Gazette*, have effect only in such modified form or shall stand annulled, as the case may be, so however that any such modification or annulment shall be without prejudice to the validity of anything previously done under that rule."

(2) It extends to the whole of the State of Andhra Pradesh."

Amendment of section 3.

5. In section 3 of the principal Act,—

(*i*) in sub-section (1)—

(*a*) for the words " Andhra Area of the State of Andhra Pradesh ", the words " State of Andhra Pradesh " shall be substituted ;

(*b*) for the words " six paise ", the words " three paise " shall be substituted ;

(*c*) for the words " two annas " in the two places where they occur, the words " twelve paise " shall be substituted ;

(*ii*) in sub-section (4), for the words " two annas ", the words " twelve paise " shall be substituted.

Amendment of section 5.

6. In sub-section (1), of section 5 of the principal Act, for the words " Official Gazette " the words " Andhra Pradesh Gazette " shall be substituted.

Amendment of section 7.

7. In sub-section (1) of section 7 of the principal Act, for the words " two annas " the words " twelve paise " shall be substituted.

Amendment of section 9.

8. In section 9 of the principal Act,—

(*i*) for sub-section (1), the following sub-section shall be substituted, namely :—

"(1) The State Government may, by notification published in the *Andhra Pradesh Gazette*, make rules for carrying out all or any of the purposes of this Act." ;

(*ii*) for sub-section (4), the following sub-section shall be substituted, namely :—

"(4) Every rule made under this Act shall, immediately after it is made, be laid before each

THE ANDHRA PRADESH ELECTRICITY DUTY (EXTENSION AND AMENDMENT) ACT, 1968*

ACT NO. 8 OF 1968.

[*5th August*, 1968.]

An Act to extend the Andhra Pradesh (Andhra Area) Electricity Duty Act, 1939 to the whole of the State of Andhra Pradesh and further to amend it in its application to that State.

BE it enacted by the Legislature of the State of Andhra Pradesh in the Nineteenth Year of the Republic of India as follows :—

Short title.

1. This Act may be called the Andhra Pradesh Electricity Duty (Extension and Amendment) Act, 1968.

Extension of Act V of 1939 to the whole of the State of Andhra Pradesh.

2. The Andhra Pradesh (Andhra Area) Electricity Duty Act, 1939 (hereinafter referred to as the principal Act), as in force at the commencement of this Act in the territories of the State of Andhra Pradesh other than those specified in sub-section (1) of section 3 of the States Reorganisation Act, 1956 and as amended by this Act, is hereby extended to the wholeof the State of Andhra Pradesh.

Amendment of long title and preamble.

3. In the long title of, and the preamble to, the principal Act, for the words " Andhra Area of the State of Andhra Pradesh ", the words " State of Andhra Pradesh " shall be substituted.

Substitution of new section for section 1.

4. For section 1 of the principal Act, the following section shall be substituted, namely :—

Short title and extent.

" 1. (1) This Act may be called the Andhra Pradesh Electricity Duty Act, 1939.

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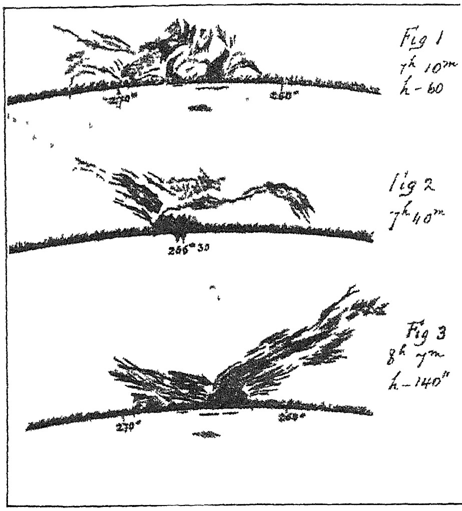
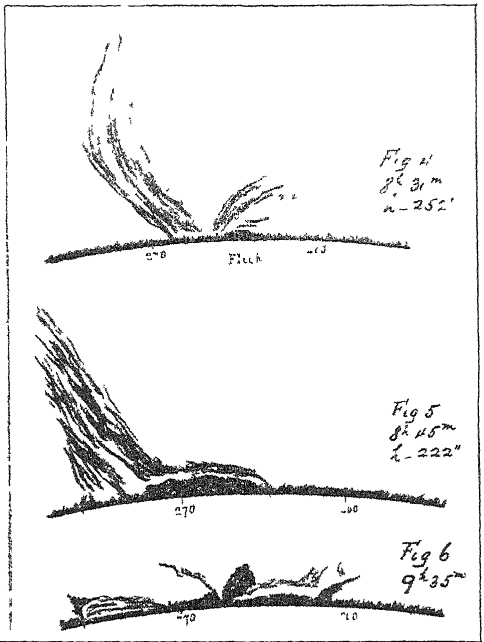
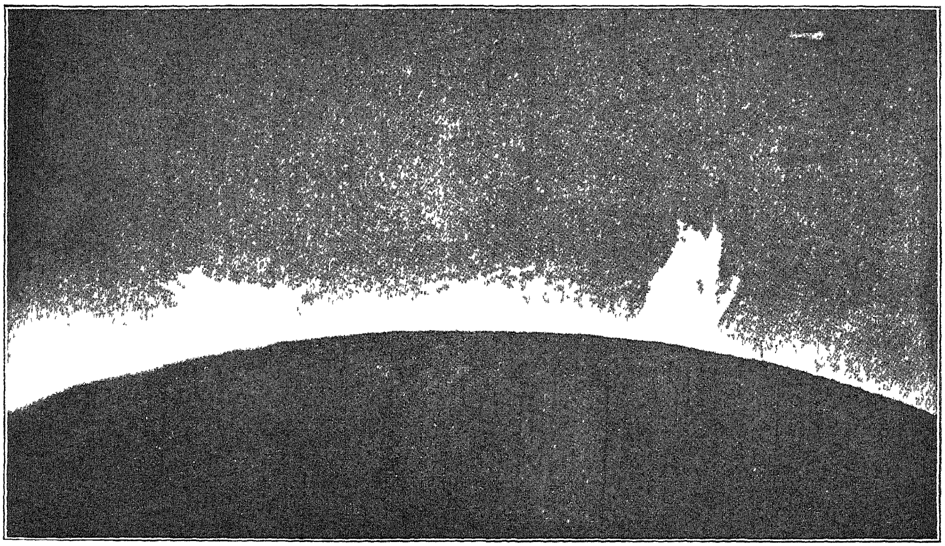
*Received the assent of the Governor on the 1st August, 1968. For Statement of Objects and Reasons, see Andhra Pradesh Gazette, Extraordinary, dated 2nd March, 1968 Part IV-A, page 4.

SOLAR PROMINENCES Drawn with the spectroscope by J FENYI, 1895 July 15th

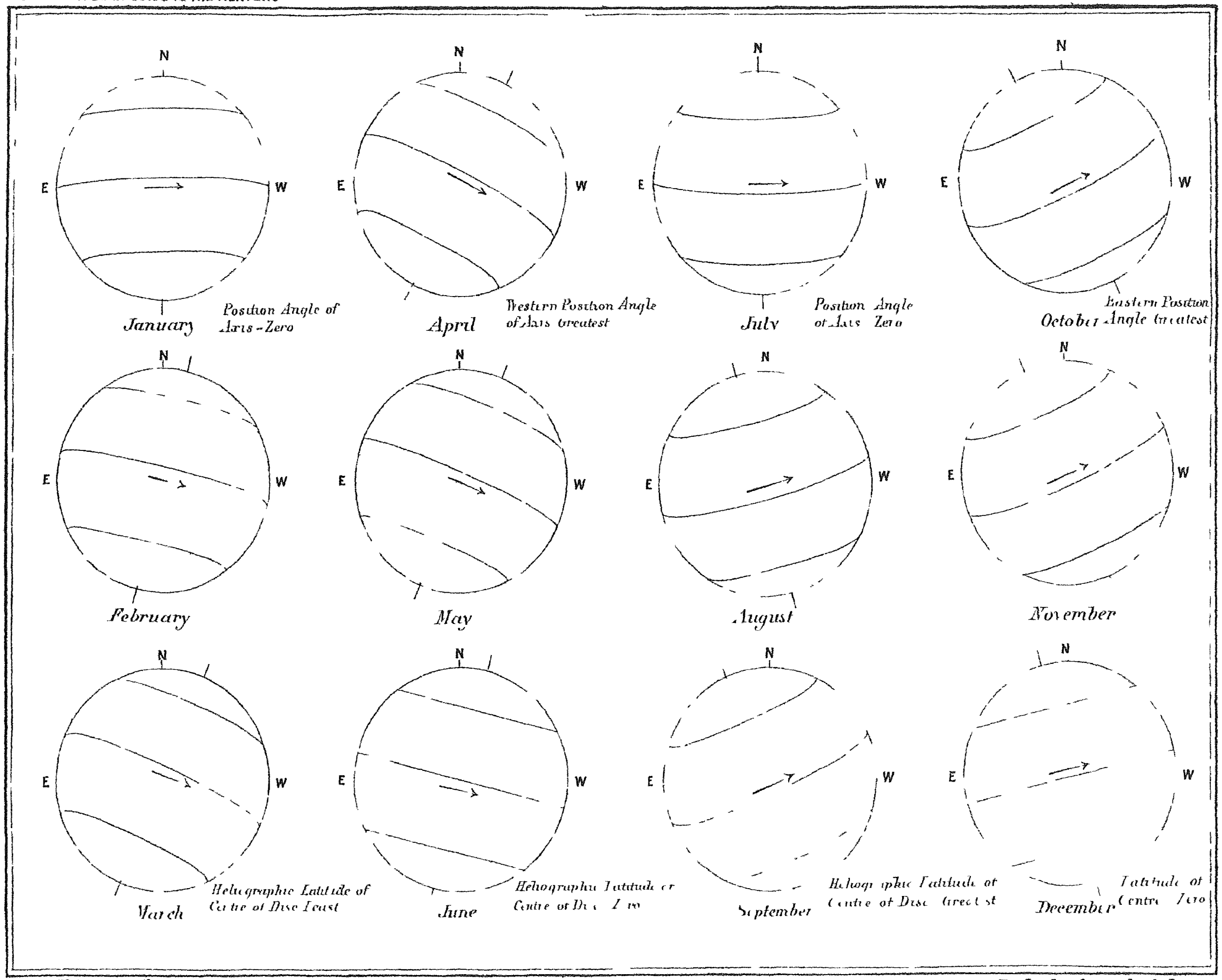






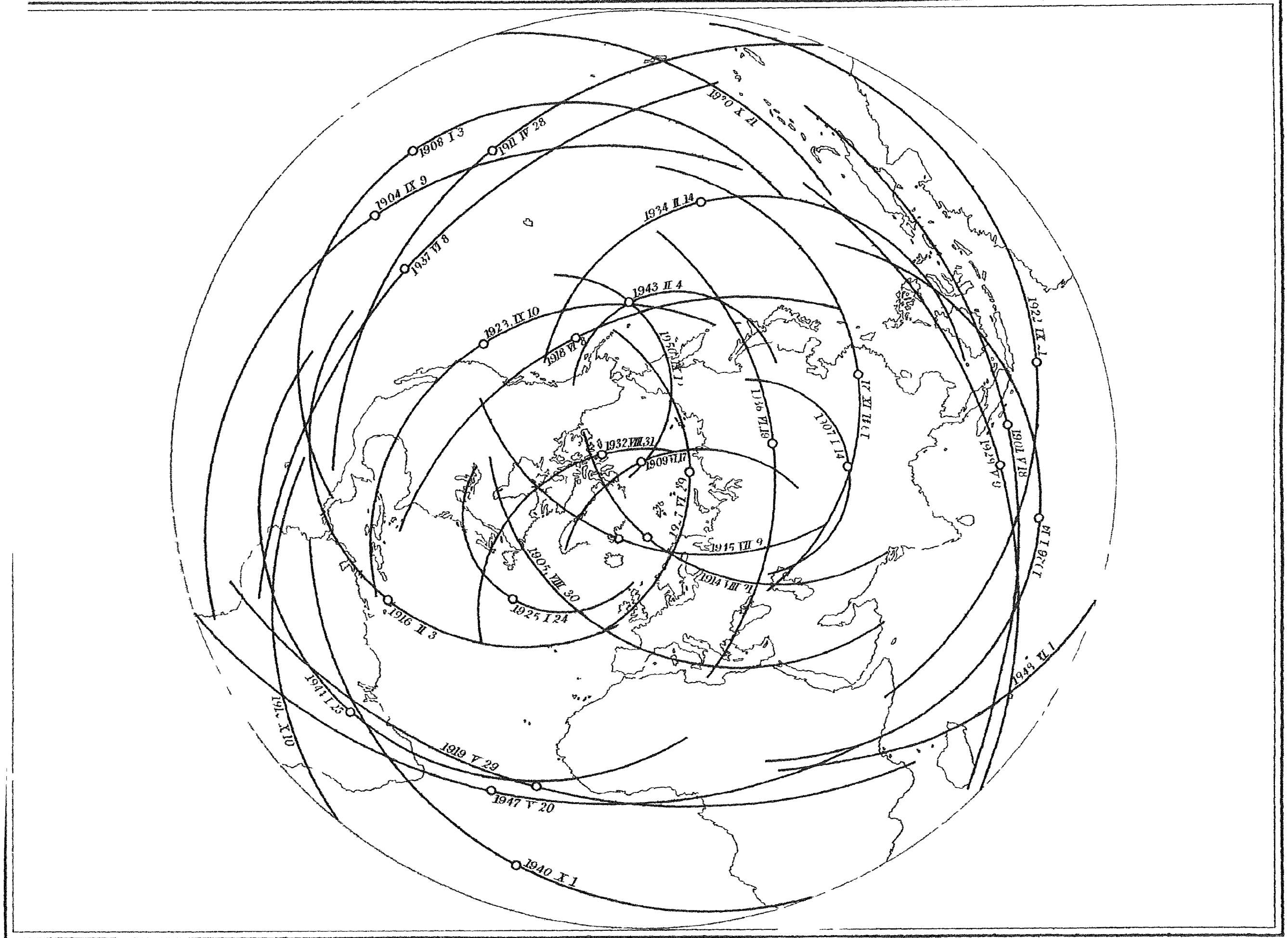
SOLAR PROMINENCES Photographed by E E BARNARD during the Total Eclipse of the Sun 1900, May 28th

PATHS OF SPOTS ACROSS THE SUNS DISC

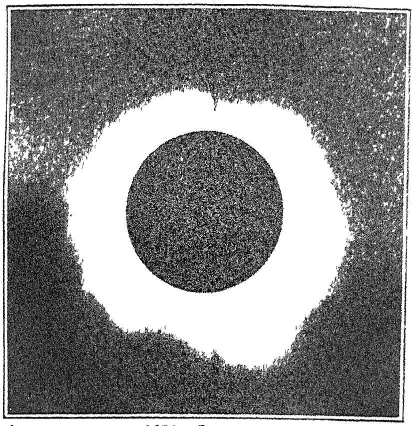


George Philip & Son Ltd
The London Geographical Institute

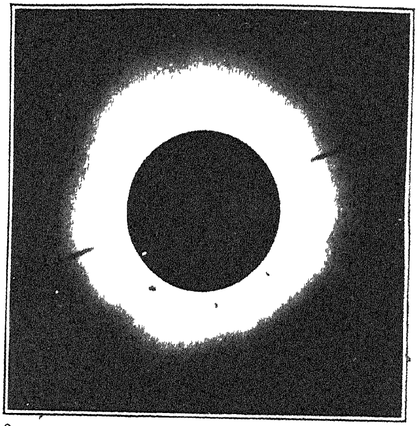
PATHS OF TOTAL SOLAR ECLIPSES 1901-1950



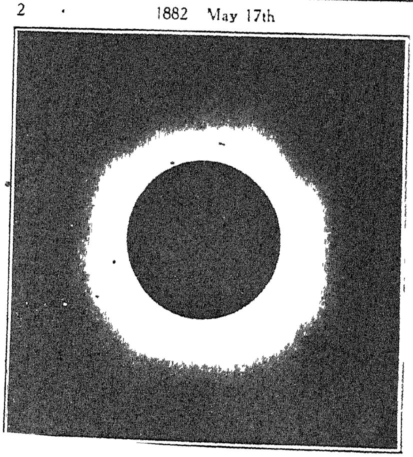
The London Geographical Institut

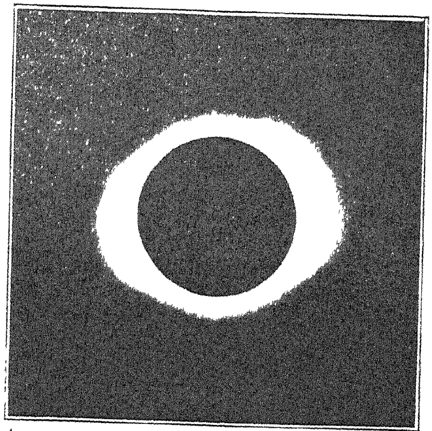


1 1871. Dec 12th.

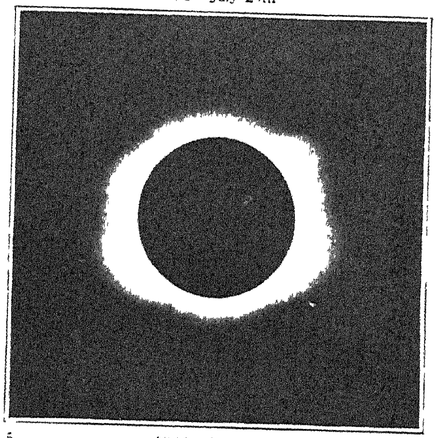


2 1882 May 17th

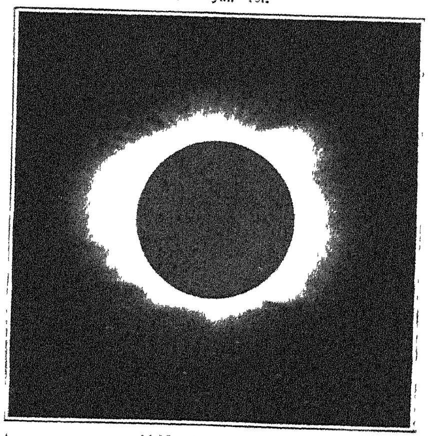




4 1878 July 29th



5 1889 Jan 1st.



1900. May 28th

CHAPTER IV.

Plate 17.

DONATI'S COMET.

This, the most famous comet of the 19th Century, was discovered by Donati at Florence, on June 2nd, 1858, as a small telescopic object approaching the Sun Not for nearly three months did it become visible to the naked eye, but thence, right up to the time of its perihelion passage, at the end of September, it grew rapidly in brightness until its starlike nucleus was as bright as the Pole star. During September its tail was directed nearly towards the Earth, and, though bright, was seen so much foreshortened that its effect was greatly marred; but as the comet passed perihelion and began to recede from the Sun, its path, by good fortune, was most favourably placed. The splendid plumed tail then lay almost at right angles to the line of sight, and its whole length was for the first time displayed. Other comets have had longer tails, though this was more than forty million miles long, but none have surpassed Donati's comet in beauty. The main tail, the curved plume, was of the type shown afterwards by the spectroscope to consist of hydrocarbons; the thin straight streamers are of the hydrogen type Evaporated, apparently, from the nucleus of the comet by the heat of the Sun, the particles of the tail are repelled from the Sun by some force whose nature is still problematical, and driven backwards from it with a speed which must be comparable with that of the speed of light itself.

On the evening of October 5th, Donati's comet was at its best, when its motion involved the bright star Arcturus in the brightest part of its tail, through which the star shone undimmed. Our plate, which was drawn by Prof. Bond, at the Harvard College Observatory, shows Arcturus close to the comet's head, while its tail sweeps up between the Great Bear and the Northern Crown.

Plate 18.

No. 1.

HOLMES' COMET AND THE ANDROMEDA NEBULA.

On Nov. 6, 1892, Mr. Edwin Holmes discovered in London a comet which was in many ways remarkable. When found it was close to the great nebula in Andromeda, and its motion was so slow that, throughout the month of November, it could be photographed on the same plate with the nebula. Plate 18 is a reproduction of a photograph taken at the Lick Observatory, on November 10th, by Professor Barnard, who describes the comet as

"round, and sharply defined like a planetary nebula, with a symmetrical, nebulous atmosphere surrounding it for some distance."

The after-history of this comet is very curious. By the middle of December, it had grown so exceedingly faint and ill-defined that scarcely any telescope could show it. But in the middle of January, it suddenly brightened up, and condensed into a small, hazy, star-like object, after which it again became diffuse, and finally vanished.

The comet's orbit was equally remarkable. It lay entirely between Mars and Jupiter, in the zone of the minor planets; and it has even been suggested that the comet was not a comet at all, but the result of some celestial accident—such as a collision—which had befallen an asteroid.

Nos. 2 and 3.

COMET a 1893, IV. (BROOKS.)

This comet, though small—and, as a visual object, insignificant—was, in some ways, the most remarkable comet that has yet been studied by photography. The plate is a reproduction of part of a series of photographs taken by Professor Barnard at the Lick Observatory. The motion of the comet was towards the north-east, the left-hand top corner of the picture. On 1893, Oct. 20th, the tail was straight, but gradually widening towards the end; on the next day, the date of the second picture, it had been completely transformed. The tail is very much distorted, as if the matter of which it is formed had encountered some resistance. On the following day, October 22nd, the tail was completely wrecked, and large portions of it were detached. In our ignorance of the way in which a comet's tail is produced and maintained, it is scarcely possible to say anything definite by way of explanation of these changes. That the comet had encountered some resisting medium is a plausible conjecture, but nothing more.

Plate 19.

COMET 1901. I.

The Great Comet of 1901, visible in the Southern Hemisphere, was by far the finest comet that had been seen for twenty years. It appeared very suddenly on April 24th, and was discovered independently by several persons in South Africa and Australia. It was then at perihelion, and visible only just before sunrise, but during the succeeding days it passed, apparently, still closer to the Sun, and was lost in the daylight. By May 3rd it was sufficiently clear of the Sun to be visible in the evening twilight, and on May 4th the photograph, from which Plate 19 is made, was taken at the Royal Observatory, Cape of Good Hope, with the Victoria telescope, in twilight. The tail is noticeably unsymmetrical, streaming from each side of the nucleus, but much more strongly on the south-west side. About this time there appeared on the same side a long, straight, faint tail, making an angle of about 30° with the axis of the main tail, and as the comet got away from the Sun into darker sky, this tail could be traced for about 25°, the extreme length of the main tail being about 7°.

COMET b 1902. III. (PERRINE)

This was an excellent example of the kind of comet which raises false hopes when it is reported in the papers as "visible to the naked eye." At its brightest it was little more conspicuous than the Andromeda nebula, with which few people are familiar as a naked-eye object; in the telescope, it was an almost formless patch of light, with a vague tail. The photograph—taken at the Royal Observatory, Greenwich, on Sept. 29, 1902—shows the tail strongly cleft Six divisions can be counted in the original from which the plate was made

This photograph was made with an exposure of 62m. The comet was in rapid motion amongst the stars, and the telescope with which the photograph was made was kept pointed precisely to it, in consequence of this, the stars appear as trails, and give a precise idea of the amount by which the comet had moved during the hour which was needed to secure this picture

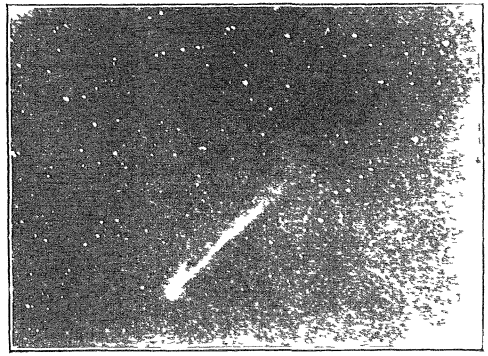
COMET OF DONATI OCT^{R} 5TH 1858.

George Philip & Son

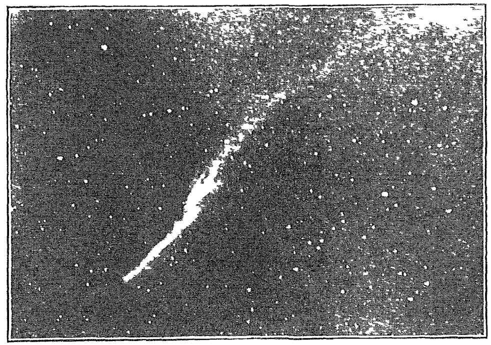
The London Geographical Institute

HOLMFS COMET AND THE ANDROMEDA NEBULA

1892 Nov 21st



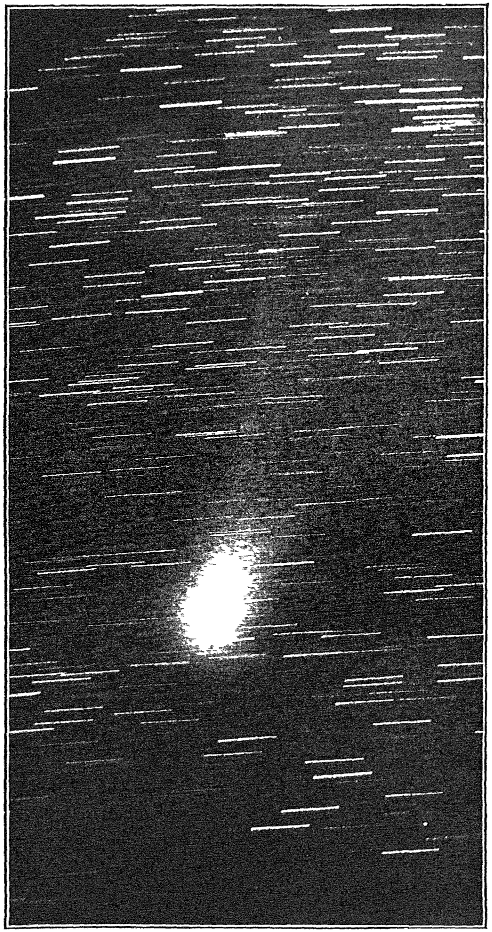
1893 Oct 20th



1893 Oct 21st

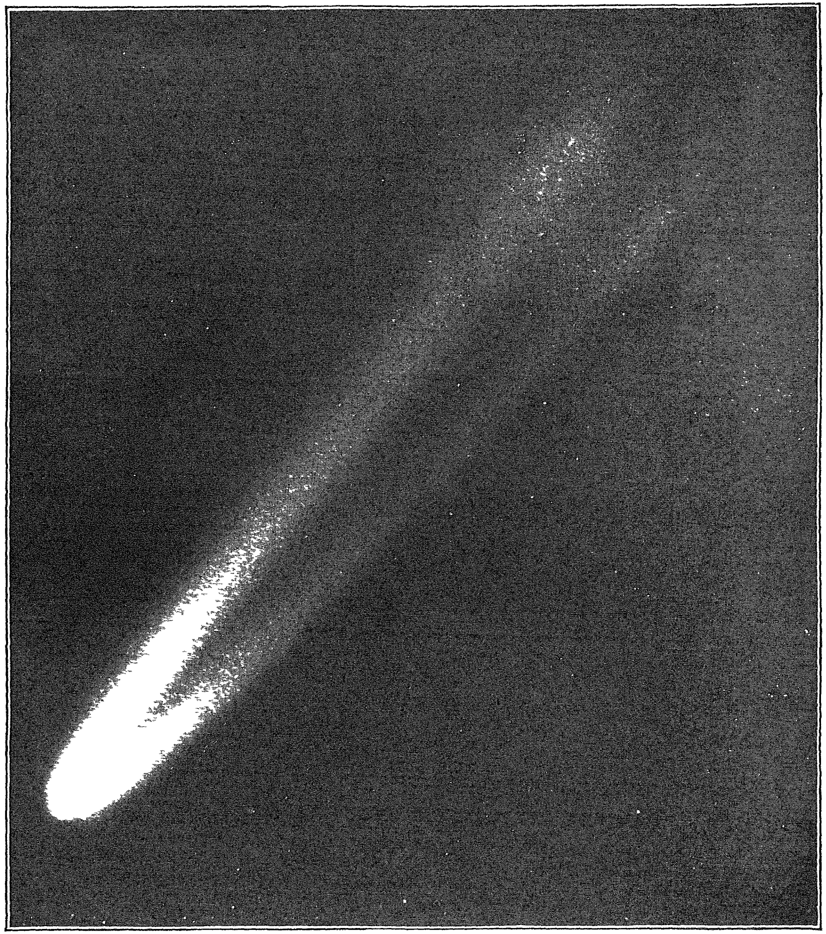
BROOKS COMET 1893 IV

From Photographs by E E BARNARD
6 in Portrait Lens LICK OBSERVATORY



PERRINE'S COMET 1902 III

30 in Reflector ROYAL OBSERVATORY GREENWICH



GREAT COMET OF 1901

May 4th McClean Telescope ROYAL OBSERVATORY CAPE OF GOOD HOPE

CHAPTER V.—THE MOON.

PLATES 20, 21 & 22.

The three photographs here reproduced were taken at the Yerkes Observatory with the great telescope, temporarily converted into a photographic telescope by the device of photographing through a screen of yellow glass in contact with the plate.

Plate 20 shows the region of the Mare Serenitatis and the Apennines. The Mare is more than 400 miles across, and is singularly free from Craters. The appearance in the photograph of the curious serpentine ridge towards its western border is a good example of the importance of selecting the right moment for studying any particular lunar object. When the photograph was taken this ridge was conspicuous had it been taken a few hours later the ridge would have disappeared It is really very low, so that it soon loses its shadow, and as soon as that happens it is no longer distinguishable.

The bright, white spot Linné has a long history. It was drawn by old observers as a deep crater. For many years it has been merely a bright spot, with scarcely any depression at all. Opinions differ widely as to the reality of any change ; perhaps, on the whole, the evidence is in favour of something having happened. But the doubt as to the trustworthiness of the old observations emphasises the value of photographs such as these, which could scarcely give a wrong verdict on such a point.

Craters differ much in their brightness ; Alfraganus and Dionysius have exceptionally brilliant walls ; Julius Cæsar and Boscovich are very dark.

The boundary of Julius Cæsar towards Sosigenes has a broken down and denuded appearance ; the deep valley alongside it has probably been formed by the fusion of several craters, which are frequently found three or four in a row close together

The Apennines and the Caucasus of the Moon are mountainous regions much more resembling those of the Earth than do the lunar mountains in general. The peaks run up to 18,000 and 20,000 feet, and the N.E boundary of the Apennines is a very steep cliff, not well shown in the photograph, which shows it under a setting sun.

There is a curious contrast between the craters Archimedes and Aristillus. The former, though 50 miles in diameter, has its crater floor only some 600 feet below the plain outside. Its walls, about 5,000 feet high, look broken and denuded, and the crater has the appearance of having been filled up nearly to the brim by an outflow of lava. In Aristillus, on the contrary, the depth from brim to floor is 11,000 feet ; the central peak and terraces are preserved, and the plain all round is covered as if with the debris of relatively late eruptions.

In Plate 21 we have a picture of the most rugged and broken part of the Moon's surface. The crater Tycho at sunrise, as shown here, is relatively undistinguished, though of such size that Mont Blanc would stand on its floor, and from its summit it would not be possible to see over the crater wall But as the Moon gets toward full, while most of the other craters become hard to see—Clavius, for example, almost entirely disappears under the perpendicular illumination—Tycho stands out conspicuously brilliant, the centre of a system of radiating bright streaks, whose nature is a mystery. They go straight across mountains and plains ; there is only one well-marked case, Saussure, in which the streak seems to turn aside to avoid a mountain

It is curious that in the district around Clavius the western walls of the craters are generally higher than the eastern. In Clavius itself, a peak of the western wall stands 17,000 feet above the floor, and the deepest of the smaller craters within is 6,000 feet deep.

At the extreme bottom of the picture, below and to the left of Pitatus, is the Straight Wall, recognised only by its shadow. The wall is almost perfectly straight, 60 miles long, and about 1,000 feet high. It is much steeper on the east than on the west side, and is, perhaps, better called a cliff than a wall.

PLATE 22 —In Copernicus and the region around it we find lunar scenery on the grandest scale. The crater itself is about 60 miles in diameter, the highest peak is more than 12,000 feet above the floor; the central mountain above 2,000 feet high The successive terraces of the wall are said to resemble those of the crater of Teneriffe: the ridges running down on to the plain suggest outpourings of lava. To the north is Mt Carpathus with an enormous cleft. To the west the whole plain is riddled like a sieve with small craters The line of these small craters running north and south, and becoming at the north end a deep cleft, suggests the question: Are these small craters formed along a pre-existing cleft, or is the cleft, as we see it, formed by the amalgamation of a number of small craters in a line?

PLACE OF THE MOON.

From the monthly maps, 39—50, the positions of the Moon at different periods in the lunation can be learned. In the first place, it is to be noted that our Satellite lies always in or close to that part of the sky marked as the "Track of the Planets" When it is full the Moon is in opposition, and comes on the meridian at midnight, and hence we have the following rule:

Look out the monthly map for the month in question, then the full Moon lies in that part of the heavens where the "Track of the Planets" crosses the central meridian, already defined to be the line drawn on the map from the North point to the South point

Example 1.—In what Constellation does the full Moon appear in September?

Solution.—The answer is given by Plate 47, where the "Track of the Planets" crosses the central meridian in Pisces, which indicates the required position

Example 2—When is the full Moon near the Pleiades?

Solution.—Plate 49 shows the Pleiades on the central meridian, and accordingly November is the answer to the question.

To find the position of the Moon at the time of the first quarter, the following is the method.

Look out the monthly map for three months *preceding* the given date, then the constellation in or near which the Moon lies at the first quarter is shown at the intersection of the "Track of the Planets" with the central meridian.

Example.—In what constellation does the first quarter Moon appear in June?

Solution—The map three months earlier is Plate 41 for March This shows the intersection of the "Track of the Planets" and the central meridian in Virgo, which is accordingly the answer required

To find the position of the Moon at the time of the last quarter, the following is the method.

Look out the monthly map for three months *following* the given date, then the Constellation in or near which the Moon lies at the last quarter is shown at the intersection of the "Track of the Planets" with the central meridian.

Example.—In what constellation does the last quarter Moon appear in July ?

Solution —The map three months later is Plate 48, which shows that the constellation is Aries.

It ought to be observed that, on account of the rapid motion of the Moon, only a rough indication of its place can be expected from the process here given, and that the accuracy will be greater the nearer the phase in question happens to the middle of the month.

The foregoing problems can also be solved by the more general method now to be described. The Table of Moon Age shows the position in the heavens which the Moon occupies at any age in any month The use of this Table is as follows.

Enter the table in the verticle column bearing the name of the month Then take the age in that column nearest the given age, and the figure at the left on the same row gives the number of the monthly map in which the region where the Moon is situated lies on the "central meridian" where the "Track of the Planets" crosses it.

THE TABLE OF MOON AGE.

Map	Jan	Feb.	March	April	May	June	July.	Aug.	Sept.	Oct.	Nov	Dec
39	14	12	10	7	5	3	29	25	23	20	18	16
40	17	14	12	10	7	5	3	27	25	23	21	19
41	19	16	15	12	10	8	5	2	28	25	23	21
42	22	19	17	14	12	10	8	5	1	0	26	24
43	25	22	21	16	14	12	10	7	4	2	28	26
44	27	25	23	18	16	14	11	9	7	4	2	29
45	29	27	25	20	18	16	14	11	9	7	5	2
46	2	0	27	25	21	18	16	14	11	9	7	4
47	5	2	29	27	24	20	18	16	14	11	10	7
48	7	4	3	0	27	23	20	18	16	14	12	9
49	10	7	5	3	0	27	23	20	18	16	14	11
50	12	9	8	5	2	0	27	23	20	18	16	14

Example 1 —Where does the Moon lie when four days old in October ?

Solution.—The October column in the Table of Moon Age being referred to, the sixth figure from the top gives 4, the age of the Moon, and the figure at the end of that row on the left is 44. This monthly map shows that the Moon must then be in or near Sagittarius.

Example 2 —What will be the age of the Moon when on the meridian at 10 P.M. in August ?

Solution.—At 10 P M. in August, the heavens will be as in Plate 45 Therefore we refer to the row for Map 45 in the Table of Moon Age, which shows, under the column August, that the moon must then be about 11 days old.

Example 3.—Determine when the Moon, at the first quarter, has a specially high altitude.

Solution —The heavens must be as in Plate 49, which refers us to the last row but one of the Table. For the Moon to be 7 days old we look under the column February, in which month the heavens are as in Plate 49 about 6 P.M.

PLATES 23 TO 38.

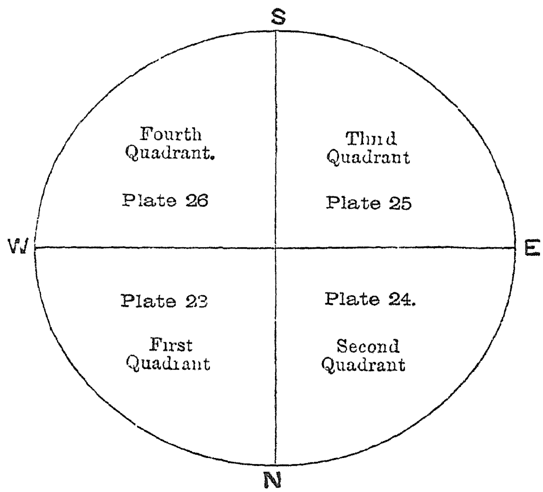
THE LUNAR OBJECTS.

For the study of the Lunar formations, Plates 23 to 38 have been specially drawn.

As the astronomical telescope shows the Moon turned upside down, and with right and left interchanged, the maps of our Satellite are represented accordingly. The four quadrants (Plates 23, 24, 25, 26) are designated in the manner shown in the annexed figure. For observations of the Moon, the "terminator" or boundary between light and shade, is the place where the objects are best seen, and Plates 23—38 of the present Atlas have been arranged to facilitate observation of the Lunar formations on the terminator at various ages, from new to full The terminators for each day of a lunation are marked on the quadrants, the morning terminator being that when the Sun is rising on the object in question. The quadrants also enable the latitudes and longitudes of Lunar objects to be found.

TERMINOLOGY OF LUNAR QUADRANTS

Moon in Inverting Telescope.



As the Moon is so much more conveniently observed from new to full, than from full to new, it is the former series of changes that have been more particularly provided for. The telescopic view of the Crescent Moon, 3 days old, is shown in Plate 27. On the opposite page an index outline is given on which each of the formations receives a special number or letter. The name of the formation may be found by looking out the number or letter in the Catalogue of Lunar formations; but for greater convenience in reference, the names of the chief objects visible in each phase are set out on the Index outline as well. As the Moon grows day by day, the terminator changes, and an ever varying series of objects is presented. A special Plate is therefore given for each day of the Moon's age, from the 3rd up to the 14th, when the Moon is full Before the third day the Moon is so close to the Sun that observations cannot be made with advantage.

Suppose, for instance, that the Moon is 9 days old. The observer then refers to Plate 33. On the terminator, a little below the middle, he notes a fine crater, and desires to learn its name. The Index outline assigns the Number 380, and the list on the margin shows that this feature is named "Copernicus." The observer will be able to trace the same object with lessening detail up to the time of Full Moon. See Plates 34 to 38. From the comparison of any one of these Plates with the figure on this page, it appears that Copernicus must lie

in the "Second Quadrant" or on Plate 24, where the great crater will be found again as No. 380, a conspicuous object at 20° East longitude, and 10° North latitude. Along the top of Plate 24 are shown the positions of the terminators at corresponding ages of the Moon It will be noted that the morning terminator on the 9th day passes through Copernicus. So also does the evening terminator on the 24th, so that if the observer desires to study Copernicus when illuminated by the sunlight from the opposite side, he may repeat his observation 15 days later.

As another illustration, let us suppose the Moon to be 4 days old, and that after comparing the Moon with Plate 28 we desire to know the name of that large round dark patch, a little below the centre, which lies midway between the limb and the terminator. The Index outline shews it marked A, and from the reference to the margin or to the Catalogue the object is identified as the Mare Crisium It is represented in Plate 23 as A near the top at the left

To show the mode of representing the ranges of Lunar mountains, we may suppose the student to be looking at the Moon a little after the first quarter, say on the eighth day, as on Plate 32. He notices a remarkable formation a little below the centre The Index outline labels this object *c*, and the margin shows that we are looking at the lunar Apennines. Plate 24 exhibits the Apennines pointing towards Copernicus.

Suppose that a view of some particular formation of known name be specially desired, the process is as follows Look it out in the Index at the end of this volume, the first reference is to the quadrant, and the next is to the plate where the object is represented on the terminator

Thus, for instance, to find the position of Plato The Index shows first of all that it lies on Plate 24, that is, in the Second Quadrant The next reference is to Plate 32, which shows the object lying near the terminator when the Moon is 8 days old. There are further references to 33, 34, and 35, where the object is also visible. The evening terminator on Plate 24 shows that when this object is suitably placed for observations with the opposite illumination, the Moon is about 23 days old. The subsequent references in the Index are to those pages of the Introduction in which the object is mentioned

The beginner should, however, be apprised that even with the assistance which it is hoped that these maps will afford him, considerable pains are often required to identify the lunar objects In the first place, various causes produce what are known as librations of the Moon, whose effect is that the Moon does not always turn precisely the same face toward us. The maps are accommodated to a state of mean libration, and the student must not be surprised if he finds an object sometimes higher and sometimes lower than its position in the map would have led him to expect. These changes often produce considerable variations in the appearance of the lunar formations. It must also be remembered that the age of the Moon cannot be always exactly that of the map which comes nearest to it. This will often involve considerable alterations in the appearance of the lunar formations from those which they present at the exact phase which the map depicts. The elucidation of the several points which thus arise will afford much interesting occupation, and will, it is hoped, lead the student to a close acquaintance with the beautiful scenery of our Satellite.

CATALOGUE OF LUNAR OBJECTS.

Figures refer to the Number of the Crater or similar formation, capital letters refer to the so-called "Seas," a small letters refer to the Mountain Ranges and isolated Mountains.

1 Langrenus.
2 Kastner
3 Vendelinus.
4 Maclaurin.
5 Hecatæus.
6 Ansgarius.
7 Petavius.
8 Wrottesley.
9 Palitzsch
10 Hase
11 Legendre
12 Wilhelm Humboldt.
13 Phillips
14 Furnerius.
15 Stevinus.
16 Snellius
17 Adams.
18 Marinus.
19 Fraunhofer.
20 Oken.
21 Vega.
22 Pontécoulant.
23 Biela
24 Hagecius
25 Boussingault.
26 Boguslawsky.
27 Schomberger
28 Webb
29 Messier.
30 Lubbock
31 Godenius.
32 Guttemberg.
33 Magelhaens.
34 Colombo
35 Cook
36 Santbech.
37 McClure.
38 Crozier.
39 Bellot
40 Borda.
41 Reichenbach.
42 Rheita.
43 Neander.
44 Metius.
45 Fabricius.
46 Janssen
47 Steinheil.
48 Vlacq
49 Rosenberger.
50 Nearchus.
51 Hommel
52 Pitiscus
53 Mutus
54 Manzinus
55 Censorinus.
56 Torricelli.
57 Capella
58 Isidorus
59 Madler
60 Bohnenberger
61 Rosse
62 Fracastorius.
63 Piccolomini
64 Stiborius
65 Riccius.
66 Rabbi Levi.
67 Zagut
68 Lindenau.
69 Nicolai
70 Busching.
71 Buch.
72 Hypatia
73 Delambre.
74 Theon Senr.
75 Theon Junr.
76 Taylor.
77 Alfraganus.
78 Kant.
79 Theophilus.
80 Cyrillus.
81 Catharina.
82 Tacitus
83 Beaumont
84 Descartes
85 Abulfeda.
86 Almanon
87 Geber
88 Abenezra
89 Azophi
90 Sacrobosco.
91 Fermat.
92 Polybius.
93 Pons.
94 Pontanus.
95 Gemma Frisius
96 Poisson
97 Aliacensis
98 Werner.
99 Apianus
100 Playfair
101 Blanchinus.
102 La Caille
103 Delaunay
104 Faye
105 Donati
106 Airy.
107 Argelander
108 Parrot.
109 Albategnius
110 Hipparchus
111 Halley
112 Hind.
113 Horrocks
114 Rhæticus
115 Reaumur.
116 Walter
117 Nonius
118 Fernelius
119 Stofler.
120 Faraday
121 Maurolycus
122 Barocius
123 Clairaut
124 Licetus
125 Cuvier
126 Bacon
127 Jacobi.
128 Lilius
129 Zach
130 Kinau
131 Pentland
132 Curtius
133 Simpelius
134 Miller.
135 Schubert
136 Apollonius
137 Firmicus.
138 Azout.

CATALOGUE OF LUNAR OBJECTS—*continued.*

139 Neper
140 Condorcet
141 Behaim
142 La Peyrouse.
143 Hanno
144 Le Gentil
145 Tannerus.
146 Huggins
147 Timoleon
148 Zeno
149 Schwabe.
150 Hansen.
151 Alhazen.
152 Picard.
153 Pierce.
154 Taruntius
155 Secchi
156 Proclus
157 Maskelyne.
158 Jansen
159 Vitruvius.
160 Maraldi
161 Cauchy.
162 Emmart
163 Oriani
164 Plutarch
165 Seneca
166 Macrobius
167 Cleomedes.
168 Tralles.
169 Burckhardt
170 Hahn
171 Berosus
172 Gauss.
173 Geminus
174 Bernouilli.
175 Messala
176 Berzelius
177 Hooke
178 Schumacher
179 Struve
180 Mercurius.
181 Franklin
182 Cepheus
183 Oersted.
184 Shuckburgh.
185 Chevallier.
186 Atlas.
187 Hercules.
188 Endymion.
189 De la Rue
190 Strabo.
191 Thales
192 Gärtner
193 Democritus.
194 Arnold
195 Moigno.
196 Peters
197 Meton.
198 Euctemon.
199 Challis.
200 Main.
201 Giòja.
202 Scoresby
203 Barrow.
204 W. C. Bond.
205 Christian Mayer.
206 Archytas.
207 Aristoteles.
208 Eudoxus
209 Alexander.
210 Egede
211 Great Alpine Valley.
212 Grove
213 Mason
214 Plana
215 Burg.
216 Baily.
217 Daniell.
218 Posidonius.
219 Chacornac
220 Le Monnier.
221 Roemer
222 Bond.
223 Maury
224 Littrow
225 Newcomb.
226 Dawes.
227 Plinius
228 Ross.
229 Maclear
230 Sosigenes.
231 Julius Cæsar
232 Boscovich.
233 Taquet
234 Menelaus
235 Sulpicius Gallus.
236 Bessel.
237 Linné.
238 Aratus.
239 Conon.
240 Manilius.
241 Ukert.
242 Triesnecker.
243 Hyginus
244 Agrippa
245 Godin.
246 Ritter.
247 Sabine
248 Dionysius.
249 Manners.
250 Arago.
251 Ariadæus.
252 Silberschlag
253 De Morgan
254 Cayley.
255 Whewell
256 Calippus
257 Theætetus.
258 Cassini
259 Aristillus
260 Autolycus
261 Mosting.
262 Lalande
263 Herschel.
264 Ptolemæus.
265 Alphonsus
266 Arzachel.
267 Alpetragius
268 Lassell.
269 Davy.
270 Guerikė.
271 Parry
272 Bonpland
273 Fra Mauro
274 Thebit.
275 Straight Wall.
276 Birt.
277 Purbach.
278 Regiomontanus.
279 Hell.
280 Pitatus
281 Hesiodus
282 Gauricus.
283 Wurzelbauer.
284 Sasserides.
285 Ball.
286 Lexell.
287 Nasireddin
288 Orontius.

CATALOGUE OF LUNAR OBJECTS—*continued.*

289 Pictet.
290 Saussure.
291 Tycho
292 Heinsius
293 Wilhelm I.
294 Longomontanus
295 Street.
296 Maginus
297 Deluc
298 Clavius
299 Cysatus
300 Moretus.
301 Short.
302 Newton.
303 Gruemberger
304 Cabeus
305 Casatus
306 Klaproth
307 Wilson
308 Kircher
309 Bettinus.
310 Zuchius
311 Segner
312 Blancanus.
313 Scheiner.
314 Weigel
315 Rost
316 Bailly
317 Schiller
318 Bayer.
319 Pingré
320 Hausen
321 Phocylides
322 Wargentin
323 Schickard
324 Drebbel
325 Inghirami
326 Hainzel.
327 Lehmann
328 Lacroix.
329 Piazzi.
330 Lagrange
331 Fourier.
332 Vieta
333 Doppelmayer.
334 Lee
335 Vitello.
336 Clausius
337 Capuanus
338 Cichus.
339 Mercator.
340 Campanus.
341 Kies.
342 Bullialdus
343 Lubiniezky
344 Nicollet
345 Hippalus.
346 Agatharchides.
347 Gassendi.
348 Hergonius
349 Letronne
350 Mersenius
351 Cavendish.
352 Byrgius
353 Eichstädt
354 De Vico.
355 Ramsden
356 Billy.
357 Hansteen
358 Sirsalis
359 Fontana
360 Zupus
361 Cruger
362 Rocca
363 Grimaldi
364 Damoiseau.
365 Riccioli
366 Lohrmann.
367 Hermann.
368 Flamsteed
369 Wichmann.
370 Euclides
371 Landsberg.
372 Gambart
373 Sommering
374 Schroter
375 Pallas.
376 Bode
377 Reinhold
378 Hortensius
379 Milichius
380 Copernicus
381 Stadius
382 Eratosthenes.
383 Gay Lussac
384 Tobias Mayer.
385 Kunowsky
386 Encke
387 Kepler.
388 Bessarion
389 Reiner.
390 Marius.
391 Hevel.
392 Cavalerius.
393 Olbers.
394 Cardanus
395 Krafft.
396 Vasco de Gama
397 Seleucus
398 Marco Polo.
399 Archimedes.
400 Beer.
401 Timocharis
402 Lambert
403 Pytheas
404 Euler
405 Diophantus.
406 Delisle.
407 Caroline Herschel.
408 Carlini
409 Leverrier.
410 Helicon
411 Kirch
412 Piazzi Smyth.
413 Plato
414 Timæus
415 Birmingham
416 Epigenes.
417 Goldschmidt.
418 Anaxagoras
419 Fontenelle.
420 Philolaus
421 Anaximenes
422 J. J. Cassini.
423 Condamine.
424 Maupertuis.
425 Bianchini
426 Sharp
427 Mairan.
428 Foucault.
429 Harpalus
430 J. F. W. Herschel.
431 Anaximander
432 Pythagoras
433 South
434 Babbage
435 Œnopides
436 Robinson.
437 Cleostratus.
438 Xenophanes.

CATALOGUE OF LUNAR OBJECTS—*continued.*

439 Repsold.
440 Harding.
441 Gérard
442 Lavoisier.
443 Ulugh Beigh
444 Lichtenberg.
445 Briggs
446 Otto Struve
447 Aristarchus
448 Herodotus
449 Wollaston
450 Schiaparelli
451 Gruithuisen.
452 Brayley.
453 Galileo.
454 Horrebow.

MOUNTAIN RANGES AND ISOLATED MOUNTAINS.

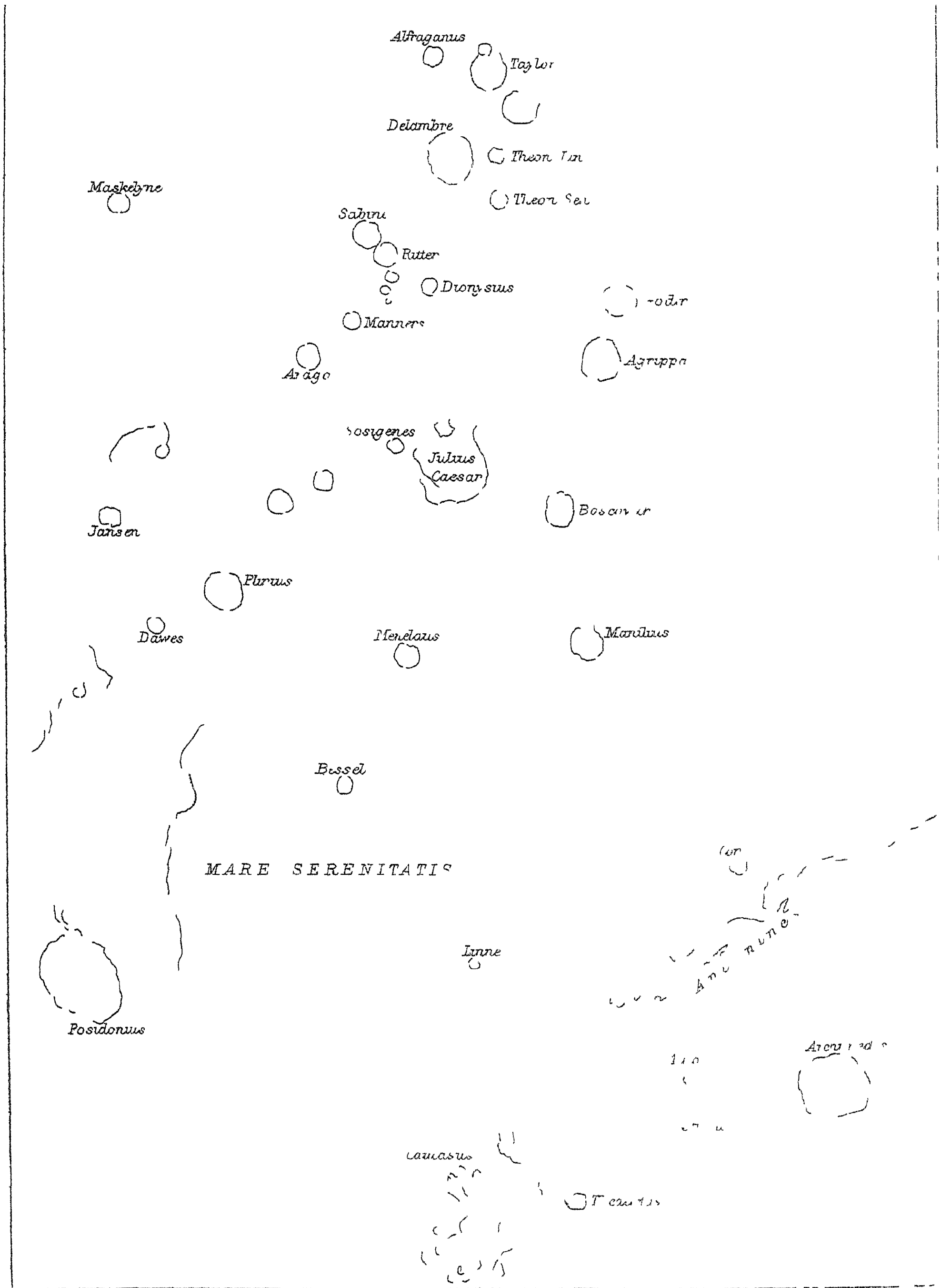
a Alps.
b Caucasus.
c Apennines.
d Carpathians
e Sinus Iridum Highlands
f Hæmus.
g Pyrenees
h Altai Mountains.
i Riphæan Mountains
j La Hire.
k Mt. Taurus
l Teneriffe Range.
m Straight Range.
n Percy Mountains.
o Harbinger Mountains.
p Hercynian Mountains
q Pico.
r Piton.
s Mt. Argæus.
t Mt. Hadley.
u Laplace Promontory.
v Mt Huygens.
w Mt Bradley.

Mountains near the Limb —

D'Alembert Mts —on the east limb, extending from S lat. 19° to N. lat 12°.
The Cordilleras—near the east limb, extending from S. lat 23° to S. lat 8°.
The Rook Mountains—on the east limb, extending from S. lat 39° to S. lat. 16°.
The Doerfel Mountains—on the south-east limb, extending from S lat 80° to S. lat. 57°
The Leibnitz Mountains extend from S. lat 70° on the west limb to S. lat. 80° on the east limb
Humboldt Mountains—on the west limb, extending from N. lat. 72° to N. lat. 53°

MARIA or SEAS

A Mare Crisium.
B „ Fœcunditatis
C „ Australe.
D „ Humboldtianum
E „ Tranquillitatis
F „ Nectaris.
G Lacus Somniorum
H „ Mortis.
J Mare Serenitatis
K „ Frigoris.
L „ Imbrium
M „ Vaporum
N Sinus Æstuum
P „ Medii.
Q Mare Nubium.
R Sinus Iridum.
S Oceanus Procellarum
T Mare Humorum
V Palus Somnii
W Sinus Roris
X Palus Nebularum
Y Mare Smythii.
Z Palus Putredinis



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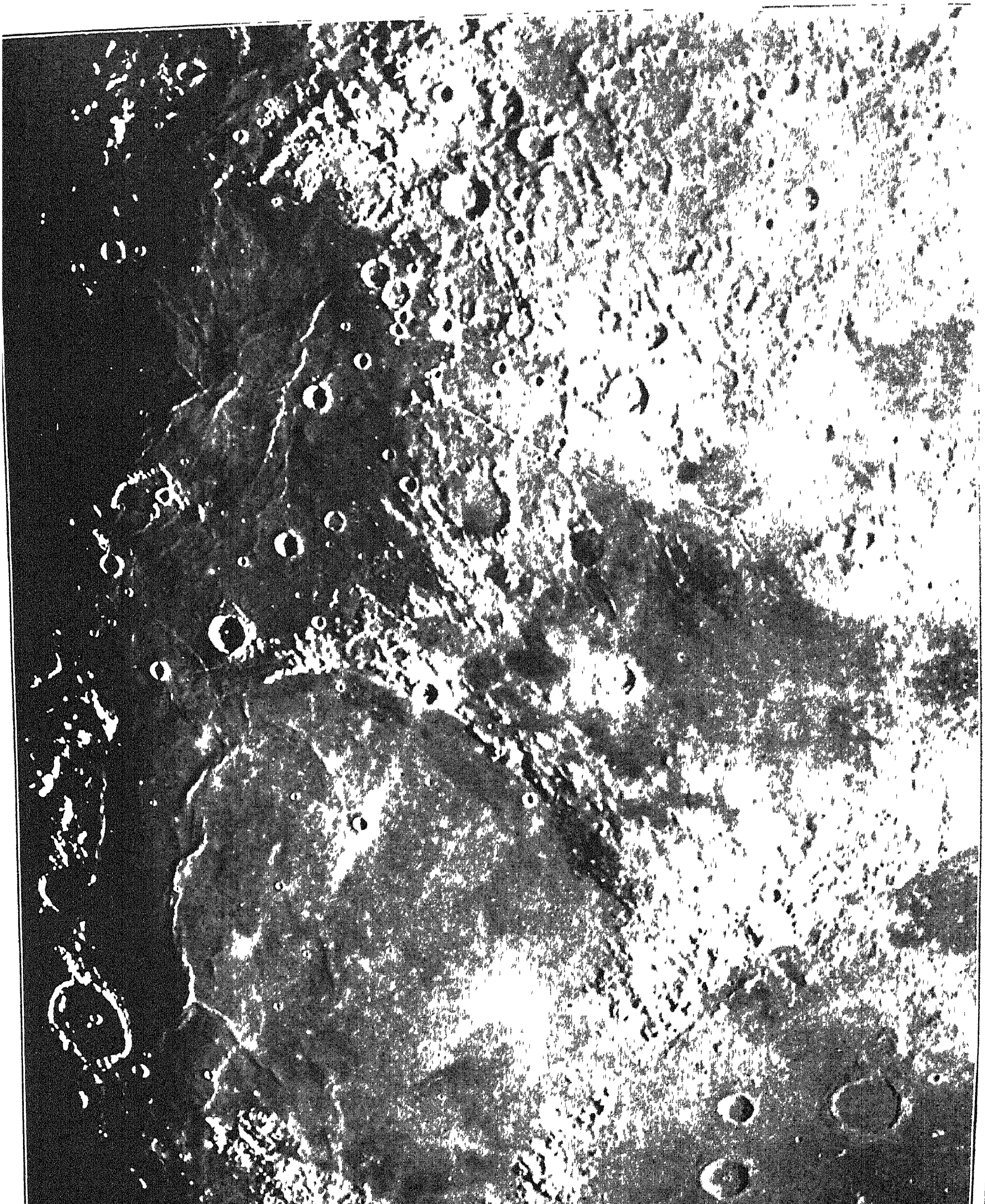
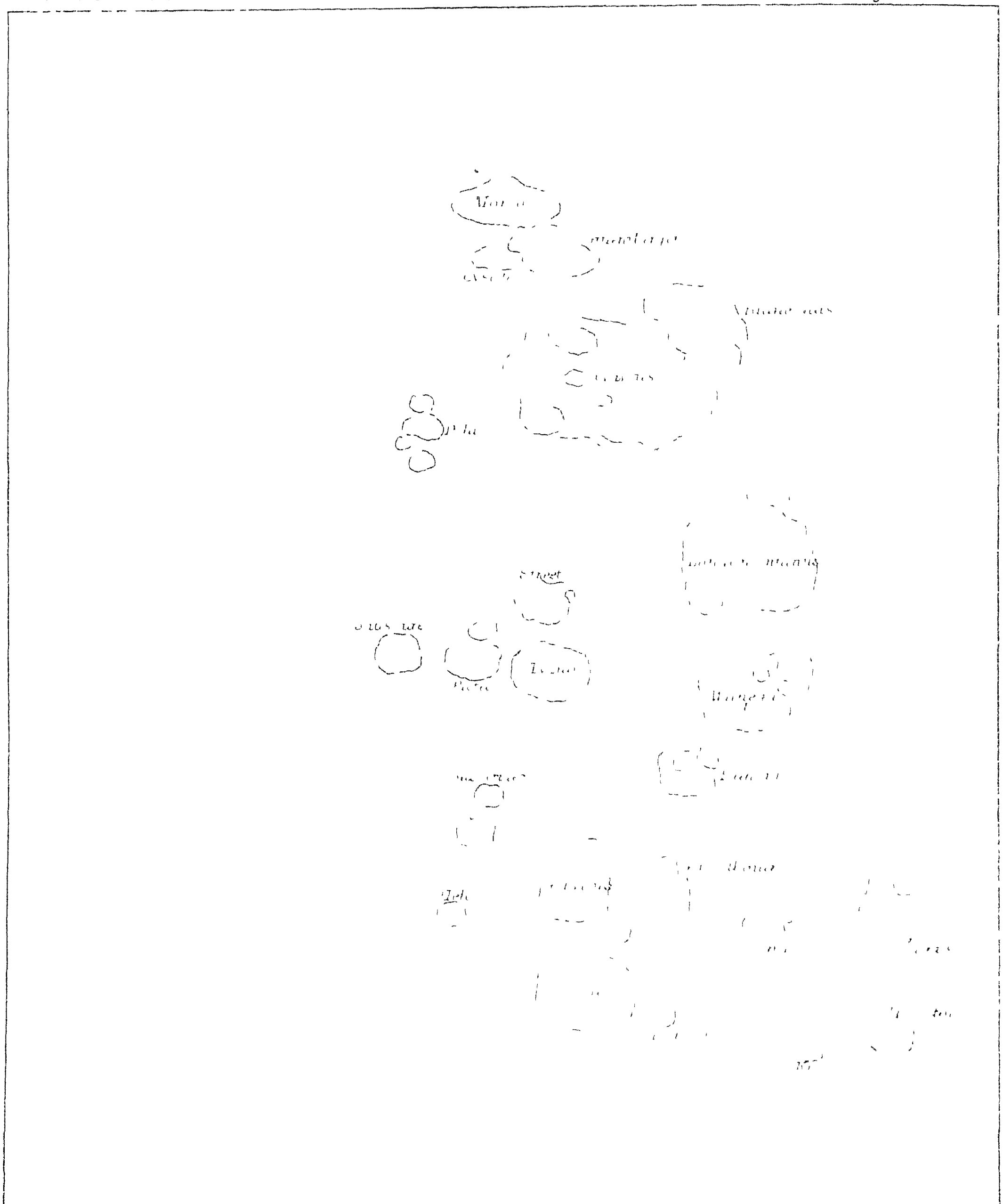
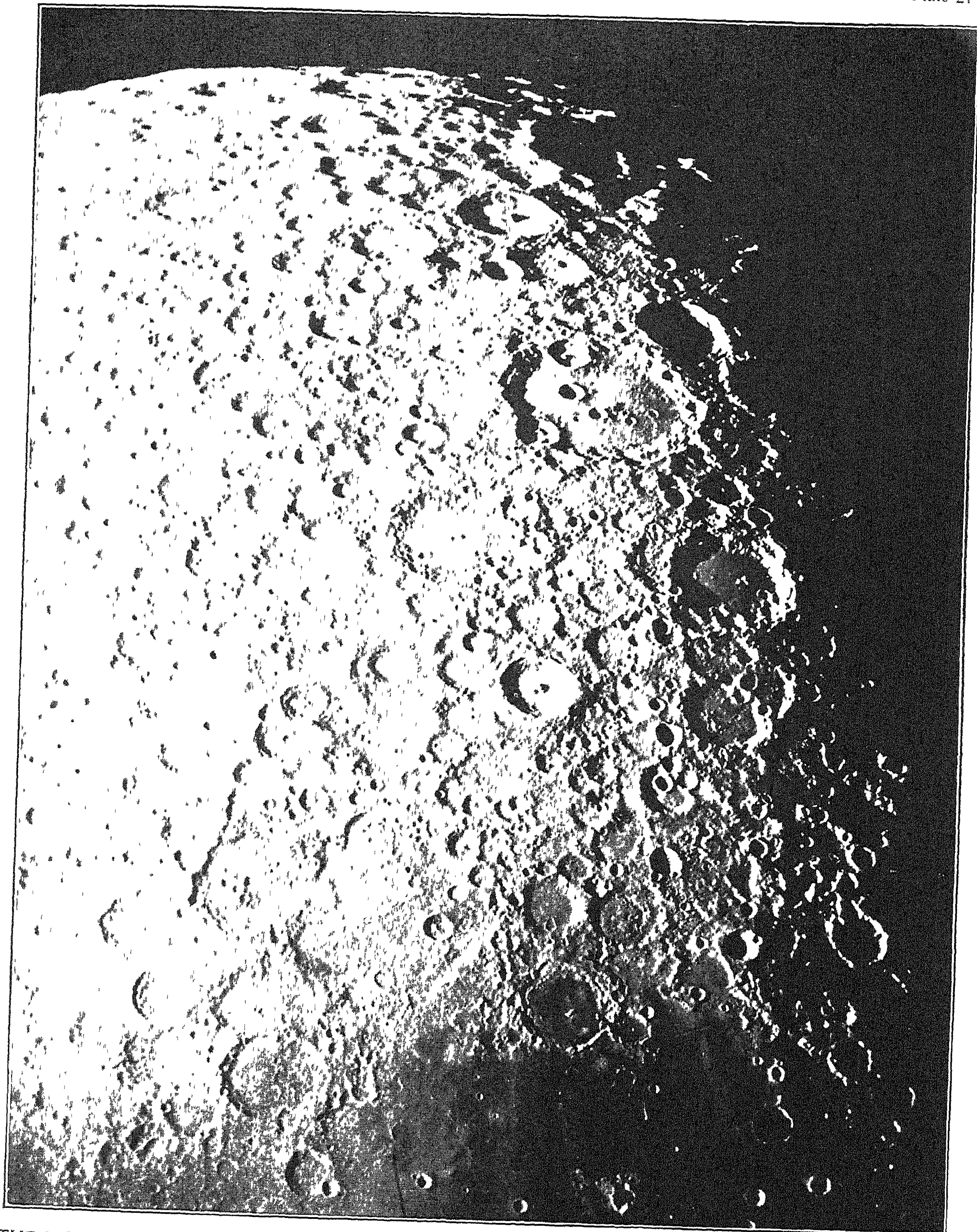
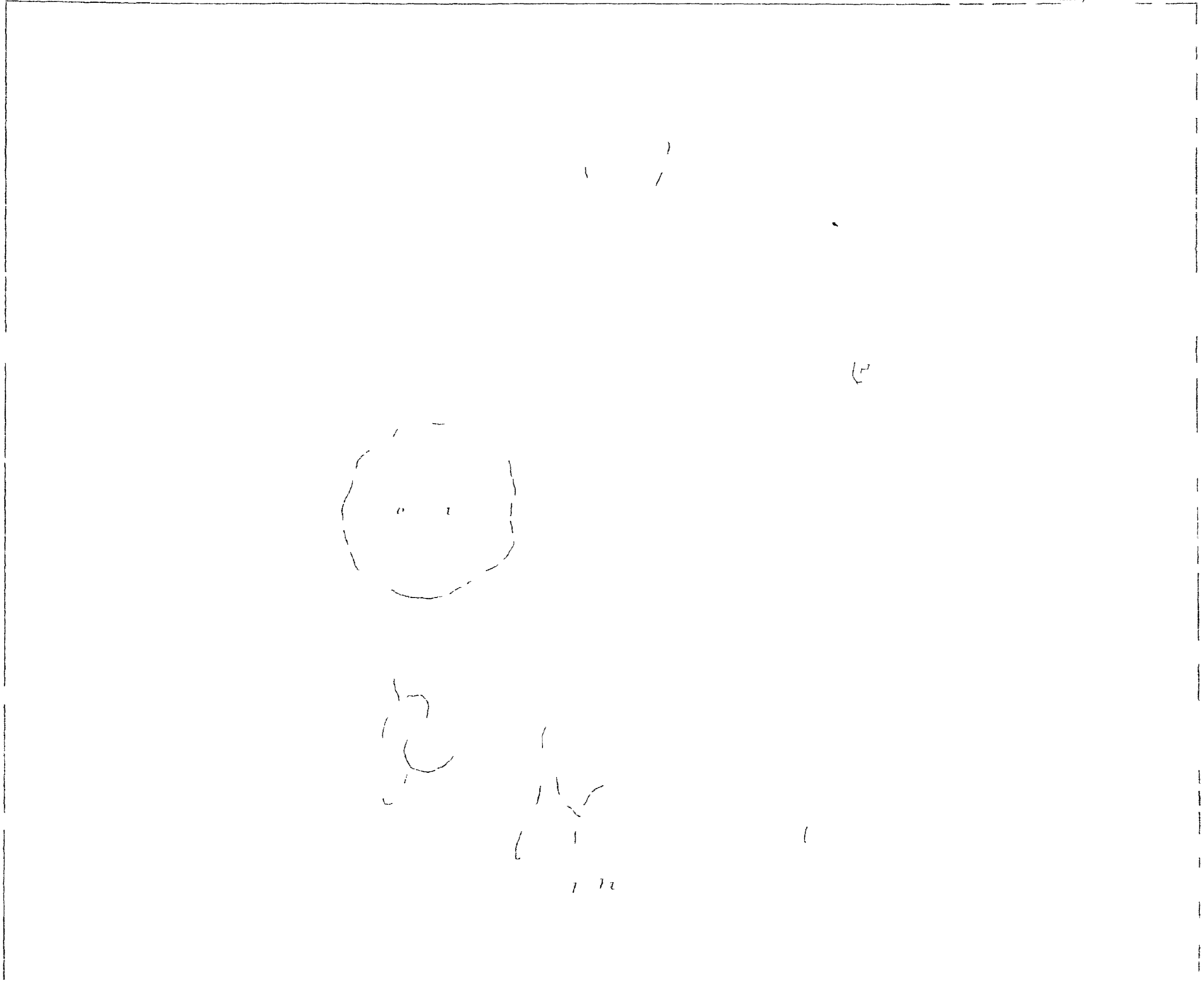


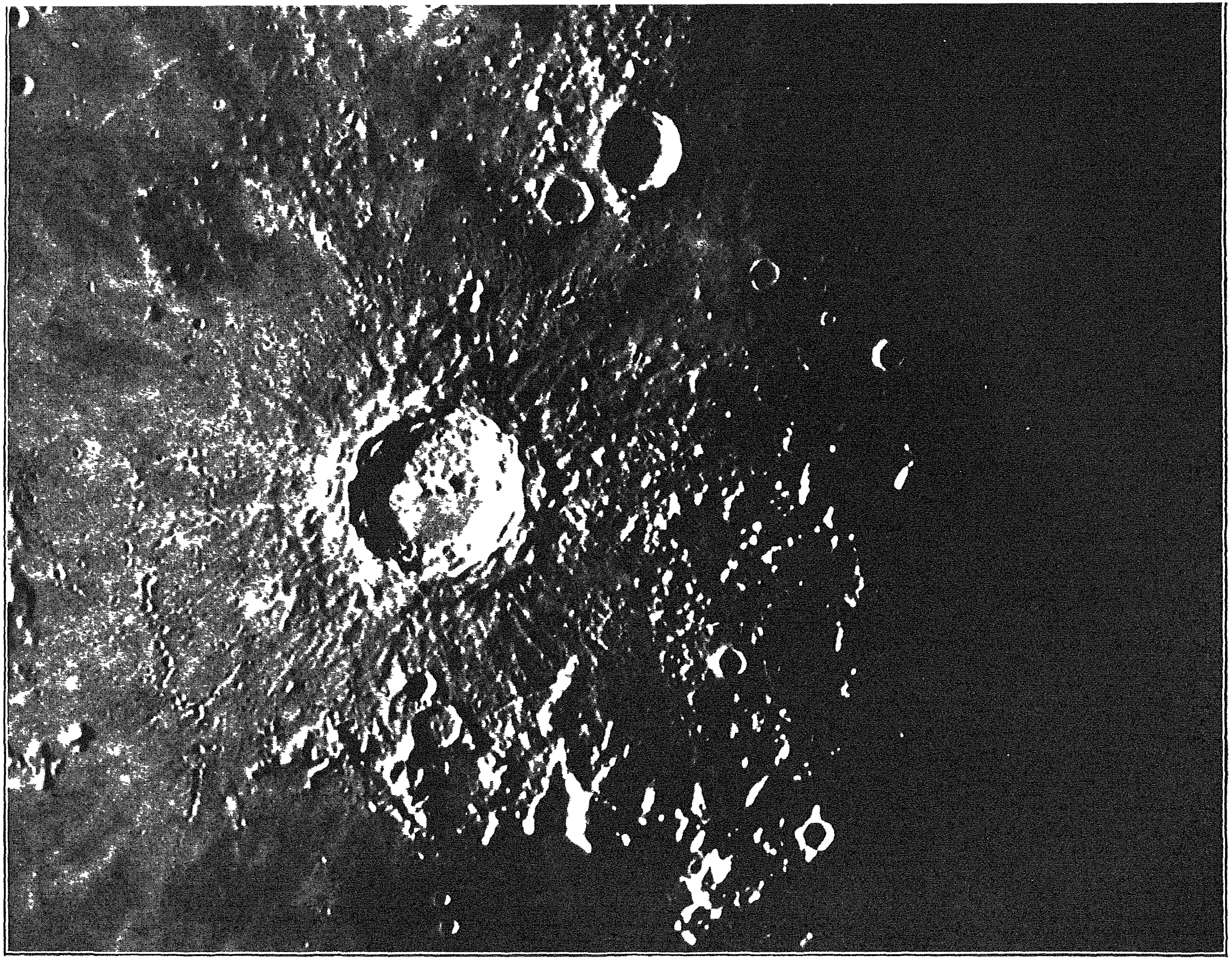
40 n. Refractor, YERKES OBSERVA





THE MOON REGION OF CLAVIUS AND TYCHO G W RITCHEY, 40-in Refractor, YERKES OBSERVATORY





THE MOON REGION OF COPERNICUS

G W RITCHEY 40 in Refractor YERKES OBSERVATORY

BALLS POPULAR GUIDE TO THE HEAVENS

CHART OF THE MOON - FIRST QUADRANT.

Plate 23

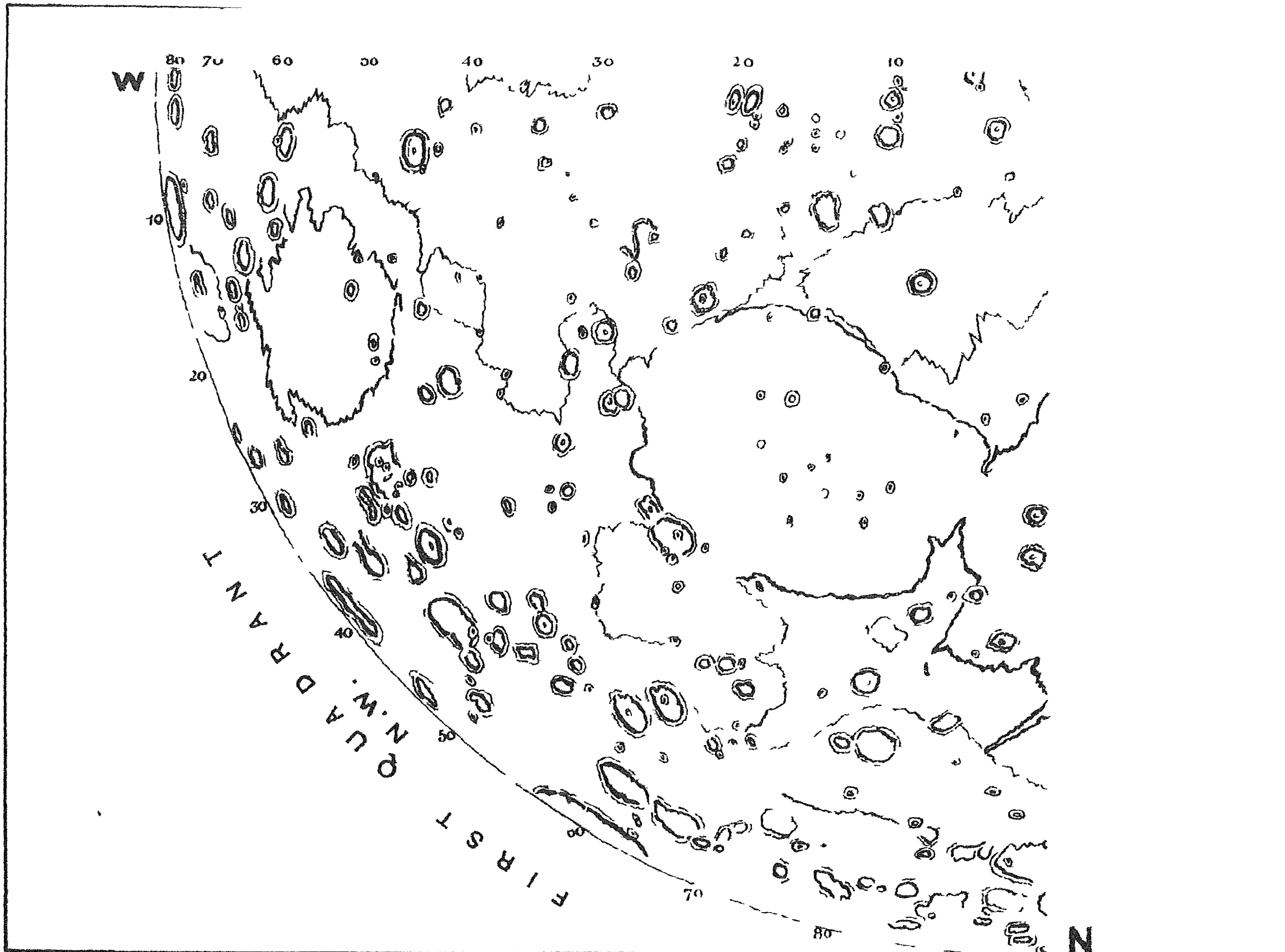


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 CHART OF THE MOON – SECOND QUADRANT.

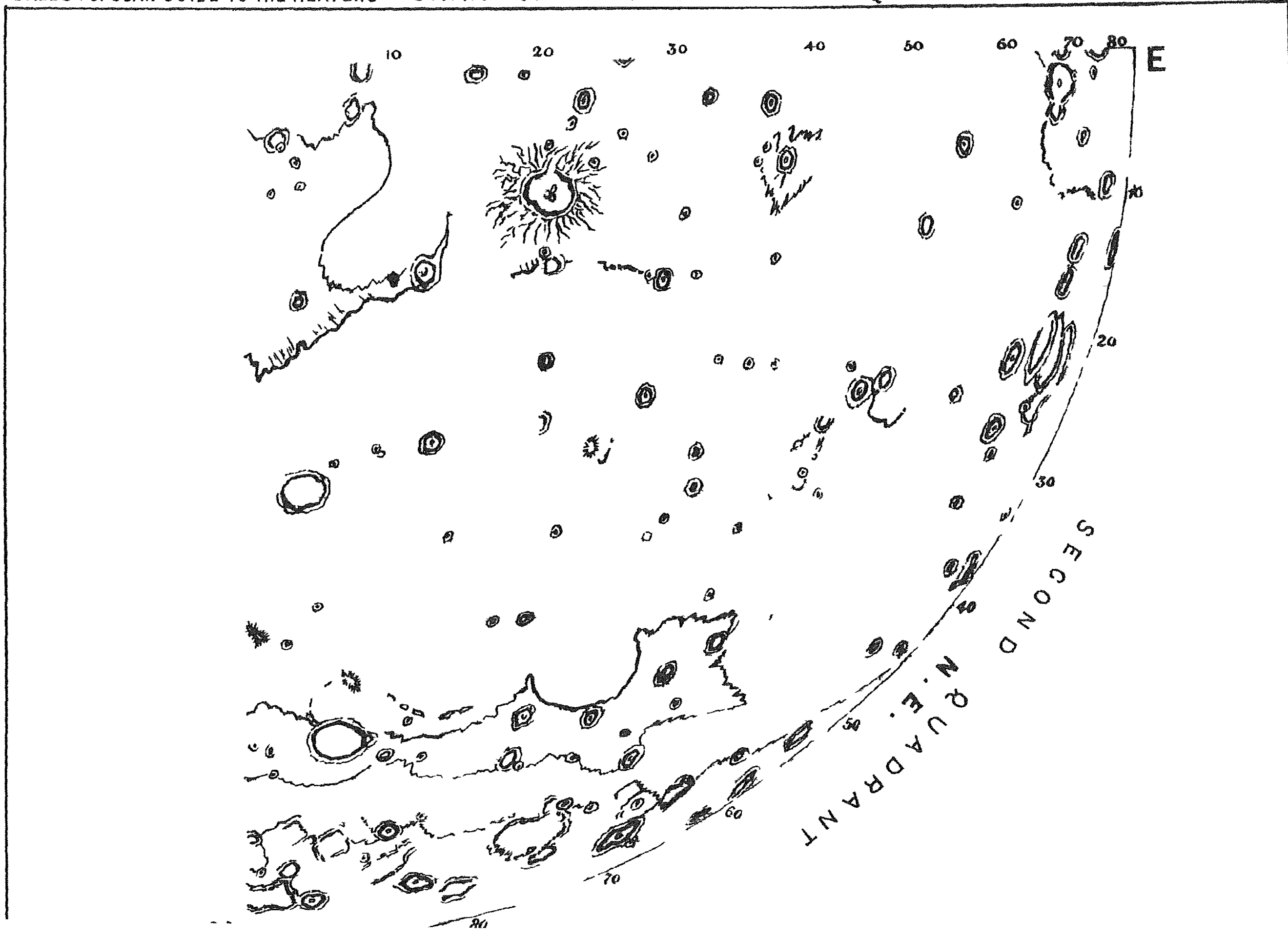

CHART OF THE MOON - THIRD QUADRANT.

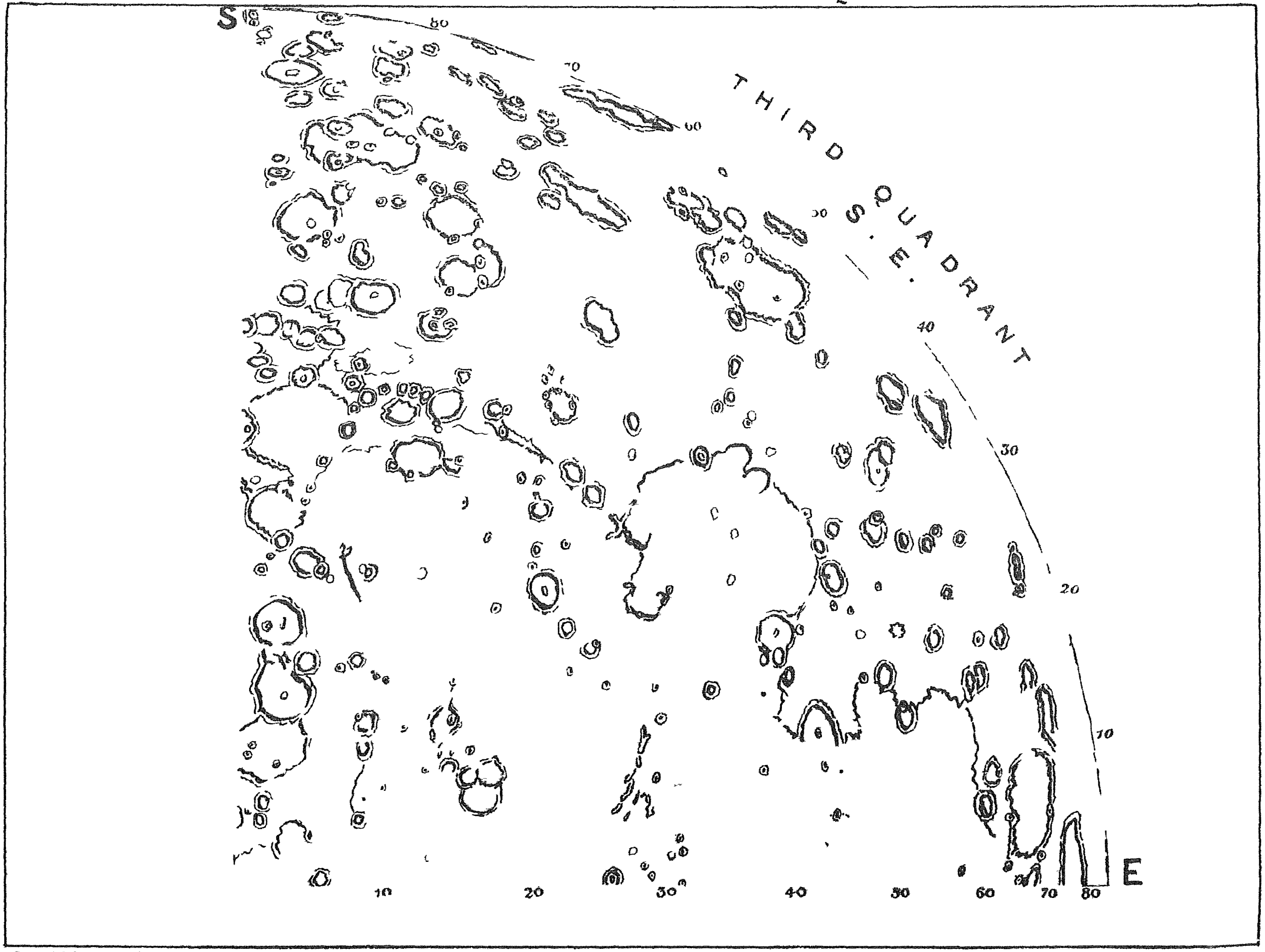

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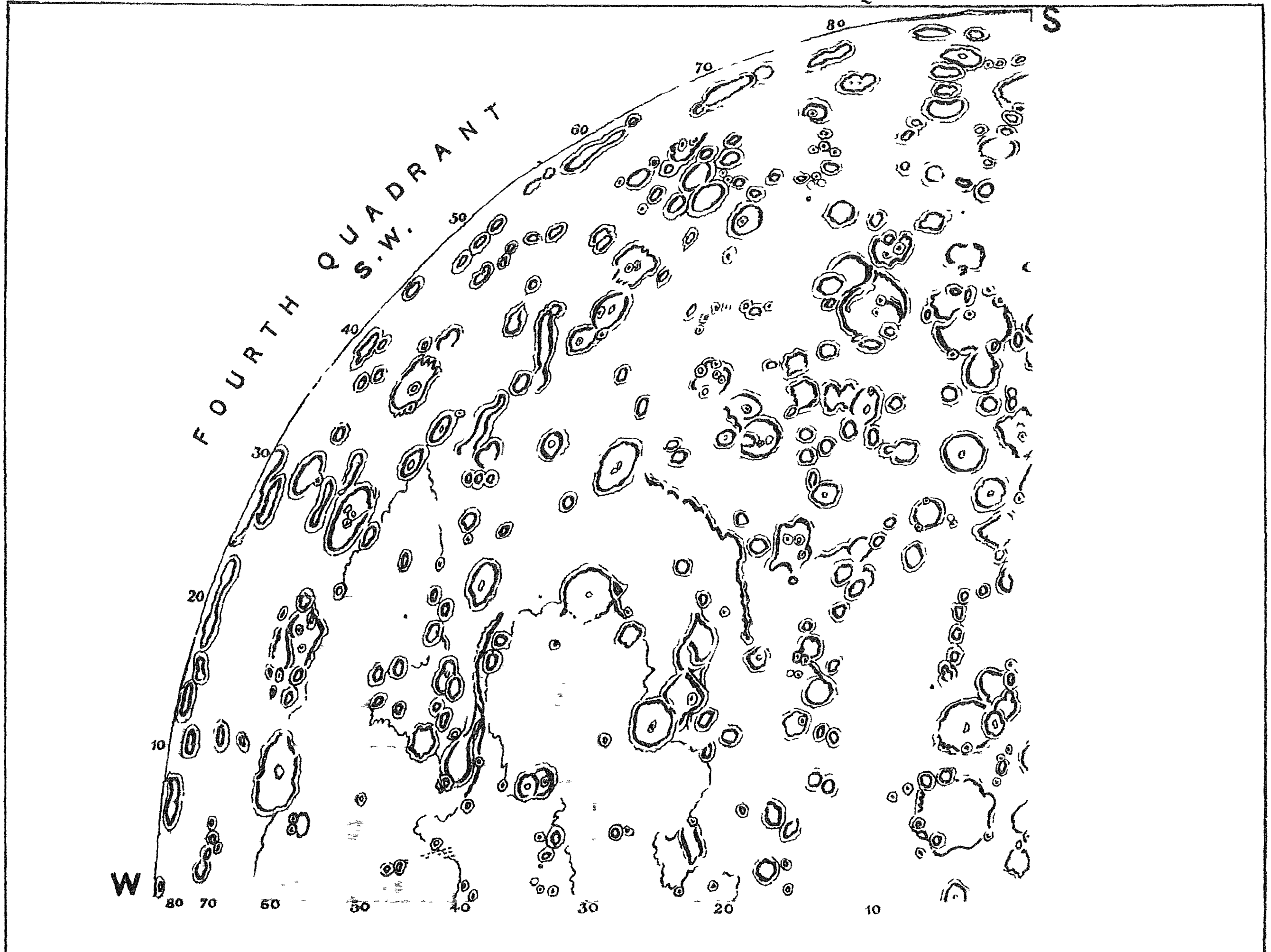
CHART OF THE MOON - FOURTH QUADRANT.



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Key Map.

THE MOON—3rd Day.

25 *Boussingault*

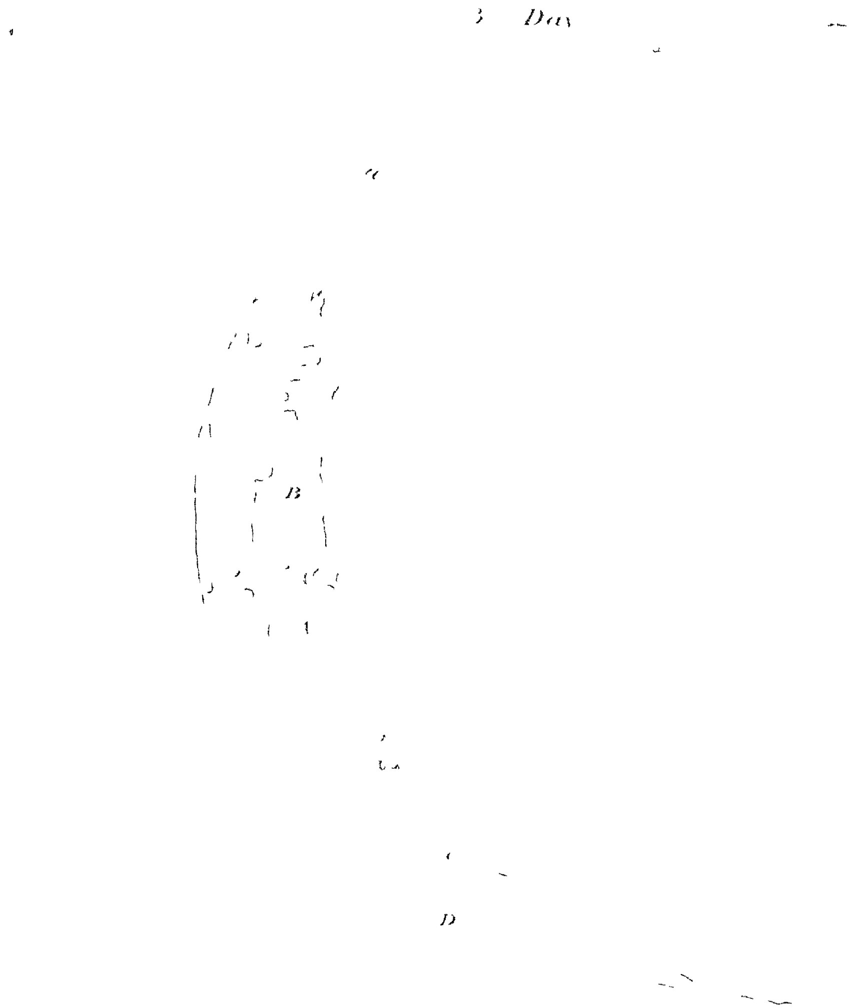
22 *Pontécoulant.*

19 *Fraunhofer.*

14. *Furnerius*

12 *W Humboldt.*

7. *Petavius.*



A *Mare Crisium.*

B ,, *Fœcunditatis.*

C ,, *Australe.*

D ,, *Humboldtianum.*

To face Plate 27.

11 *Legendre.*

5. *Hecatæus.*

3. *Vendelinus*

1. *Langrenus.*

2. *Kastner.*

136. *Apollonius*

137 *Firmicus*

139. *Neper.*

140. *Condorcet*

152 *Picard.*

151 *Alhazen.*

153. *Peirce.*

167. *Cleomedes.*

169. *Burckhardt.*

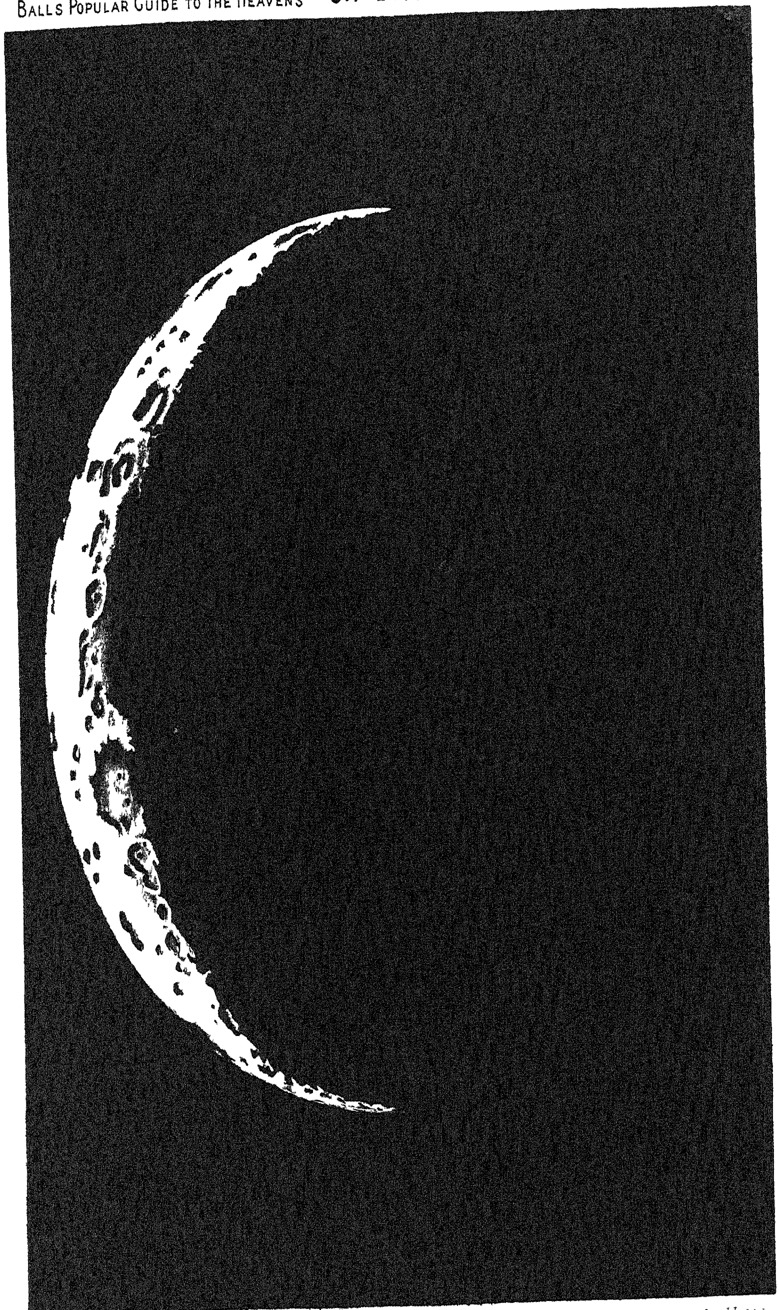
173. *Geminus.*

172. *Gauss.*

175 *Messala.*

180 *Mercurius.*

188 *Endymion.*



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Key Map. THE MOON—4th Day. To face Plate 28.

26. *Boguslawsky.*
25. *Boussingault.*
22. *Pontécoulant.*

49 *Rosenberger.*
46. *Janssen.*
45 *Fabricius*

44 *Metius.*
14. *Furnerius.*
15. *Stevinus.*
43. *Neander.*
41. *Reichenbach.*
16. *Snellius.*
7. *Petavius.*
36. *Santbech.*
34. *Colombo.*
3. *Vendelinus*
31. *Godenius.*
32. *Guttemberg*
1. *Langrenus.*
30. *Lubbock.*
29. *Messier.*
155. *Secchi.*
136. *Apollonius.*
154. *Taruntius.*
152. *Picard.*
153. *Pierce.*
156. *Proclus.*
166. *Macrobius.*
167. *Cleomedes.*
169. *Burckhardt*
172. *Gauss.*
176. *Berzelius.*
175. *Messala.*
181. *Franklin.*
185. *Chevallier.*
186. *Atlas.*
180. *Mercurius.*
188. *Endymion*
189. *De La Rue.*

A *Mare Crisium.*
B ,, *Faecunditatis.*
C ,, *Australe.*
D ,, *Humboldtianum.*

V *Palus Somnii*

g. *Pyrenees Mts.*

27. *Schomberger.*
54 *Manzinus.*
53. *Mutus.*

49. *Rosenberger.*
48. *Vlacq.*
52. *Pitiscus.*

46. *Janssen.*
45. *Fabricius.*
44. *Metius.*
14. *Furnerius.*
64. *Stiborius.*
63. *Piccolomini.*
62. *Fracastorius.*
36. *Santbech.*
7. *Petavius.*
3. *Vendelinus.*
31. *Godenius.*
32. *Guttemberg.*
1. *Langrenus.*
58. *Isidorus.*
57. *Capella.*
29. *Messier.*
159 *Vitruvius.*
220. *Le Monnier.*
221. *Roemer.*
219. *Chacornac.*
224. *Littrow.*
218. *Posidonius.*
214. *Plana.*
187. *Hercules.*
186. *Atlas.*
188. *Endymion*
189. *De La Rue.*
198. *Euctemon.*

A *Mare Crisium*
B ,, *Fœcunditatis*
E ,, *Tranquillitatis.*
F , *Nectaris.*

D *Mare Humboldtianum.*
G *Lacus Somniorum.*
H ,, *Mortis.*

g. *The Pyrenees.*
k. *Taurus Mts.*

126 *Bacon*
121 *Maurolycus*

71 *Buch*
64. *Stiborius*
65. *Riccius*

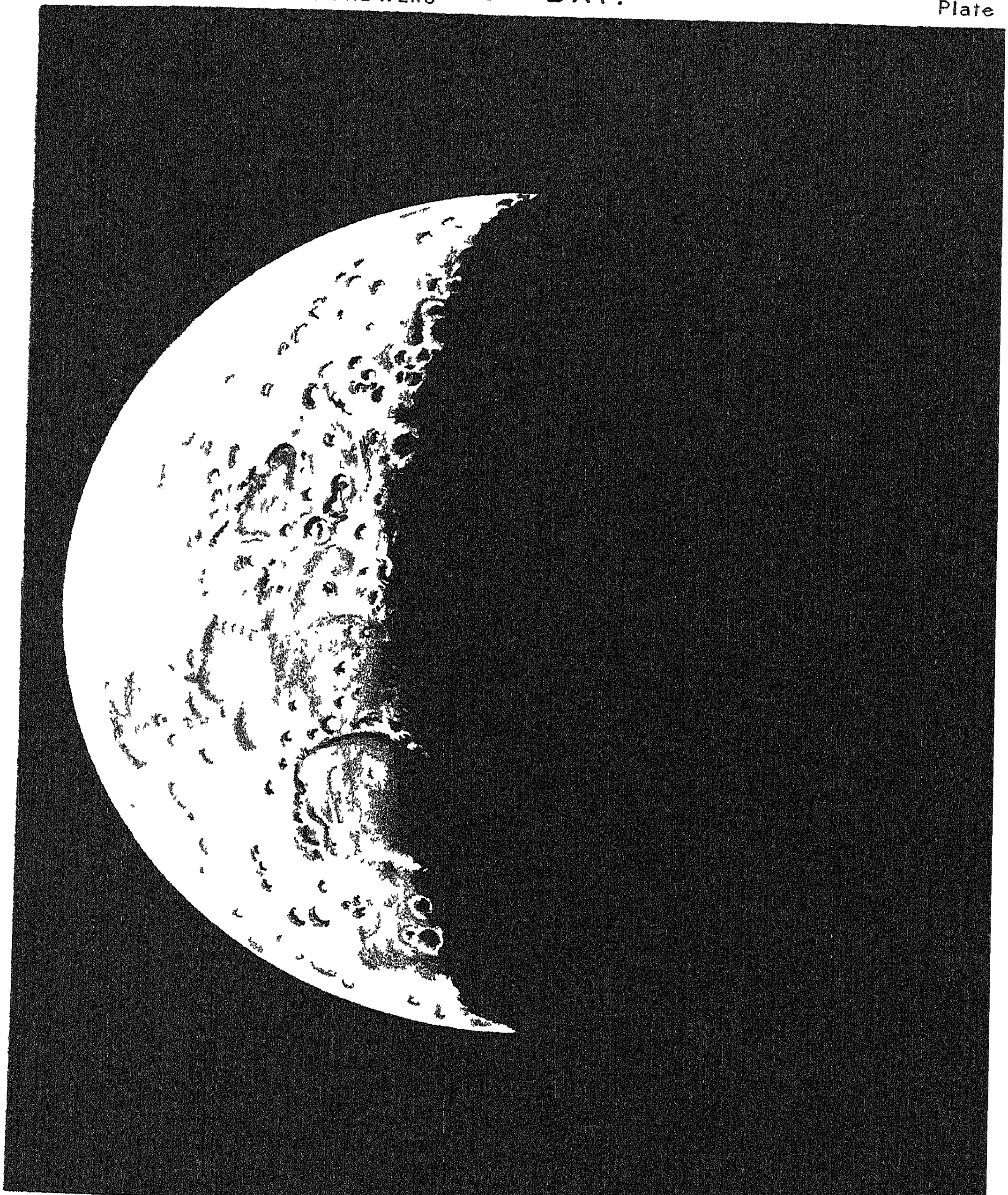
66 *Rabbi Levi*
67 *Zagut*
63 *Piccolomini*
93 *Pons.*
62 *Fracastorius*
90. *Sacrobosco*
91. *Fermat*
81. *Catharina.*
82 *Tacitus*
80 *Cyrillus.*
59 *Madler*
79 *Theophilus*
72. *Hypatia*
247. *Sabine*
246 *Ritter.*
250. *Arago.*
229 *Maclear.*
228 *Ross*
227 *Plinius*
226 *Dawes.*
236 *Bessel*
220 *Le Monnier.*
219 *Chacornac.*
218 *Posidonius.*
208 *Eudoxus*
207 *Aristoteles.*
197 *Meton*
202 *Scoresby*

A *Mare Crisium*
B ,, *Fœcunditatis*
D ,, *Humboldtianum*
E ,, *Tranquillitatis*

F *Mare Nectaris.*
G *Lacus Somniorum.*
H ,, *Mortis*
J *Mare Serenitatis*

g *The Pyrenees*
h. *Altai Mts.*
k. *Taurus Mts.*
s *Mt. Argæus.*

 6TH DAY. Plate



132. *Curtius.*
129. *Zach.*
128. *Lilius.*

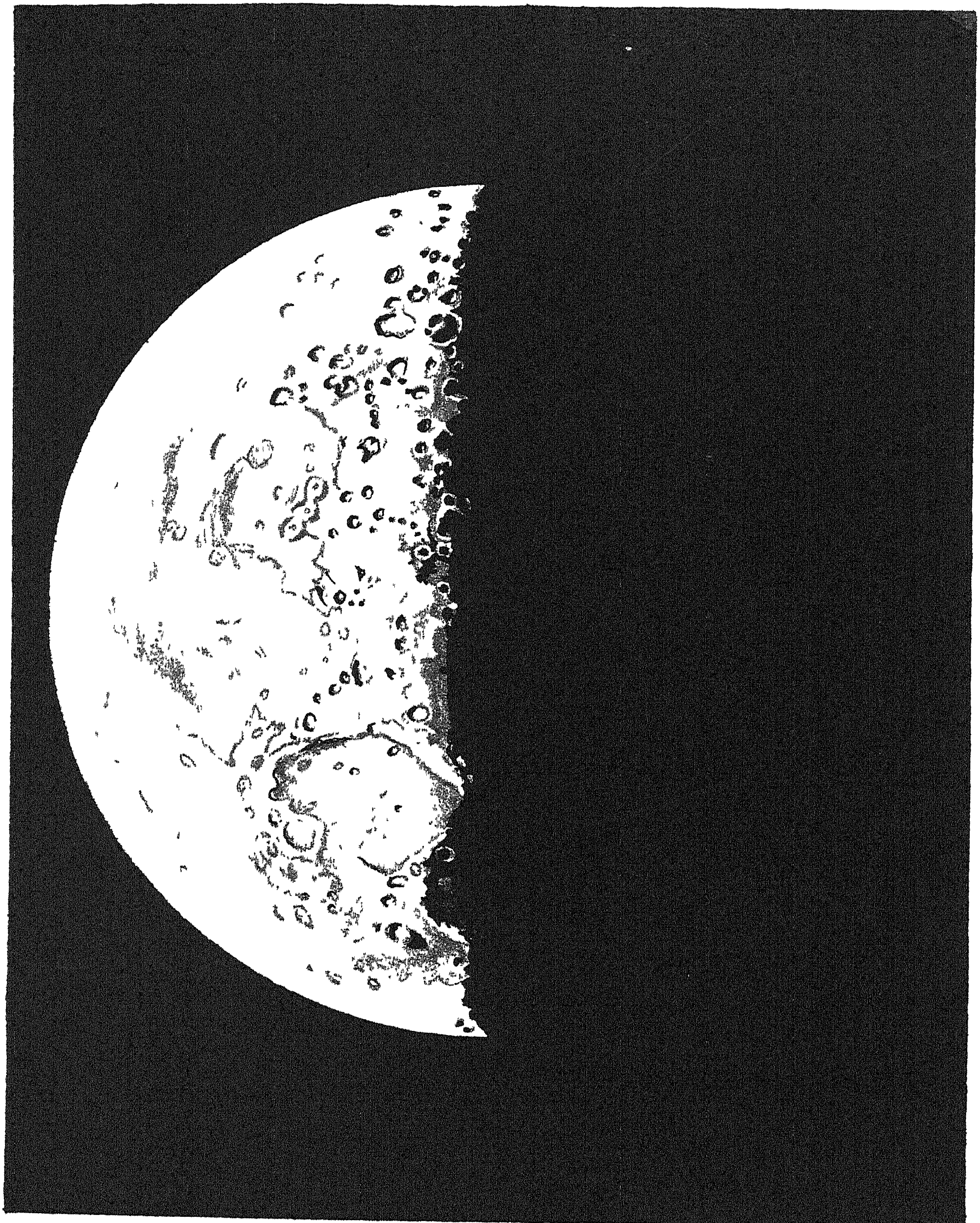
124. *Licetus.*
123. *Clairaut.*
121. *Maurolycus.*

A *Mare Crisium.*
B ,, *Fœcunditatis.*
E ,, *Tranquillitatis.*
G *Lacus Somniorum.*

F *Mare Nectaris.*
K ,, *Frigoris.*
M ,, *Vaporum.*
J ,, *Serenitatis.*

119. *Stofler.*
118. *Fernelius.*
97. *Aliacensis.*
98. *Werner.*
99. *Apianus.*
100. *Playfair.*
101. *Bianchinus.*
105. *Donati.*
106. *Airy.*
86. *Almanon.*
85. *Abulfeda.*
109. *Albategnius.*
112. *Hind.*
111. *Halley.*
110. *Hipparchus.*
113. *Horrocks.*
114 *Rhaeticus.*
245. *Godin.*
244. *Agrippa.*
242. *Triesnecker.*
232. *Boscovich.*
231. *Julius Cæsar.*
240. *Manilius.*
233. *Taquet.*
234. *Menelaus.*
236. *Bessel.*
237. *Linneé.*
257. *Theætetus.*
256. *Calippus.*
209. *Alexander.*
208. *Eudoxus.*
207. *Aristoteles.*

H *Lacus Mortis.*
X *Palus Nebularum.*
M *Mare Vaporum.*
b. *The Caucasus.*
f. *The Hæmus Mts.*
k. *The Taurus Mts.*



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Key Map. THE MOON—8th Day. To face Plate 32.

300. *Moretus.*
297 *Deluc*
296 *Maginus*

290 *Saussure*
116. *Walter*
285 *Ball.*

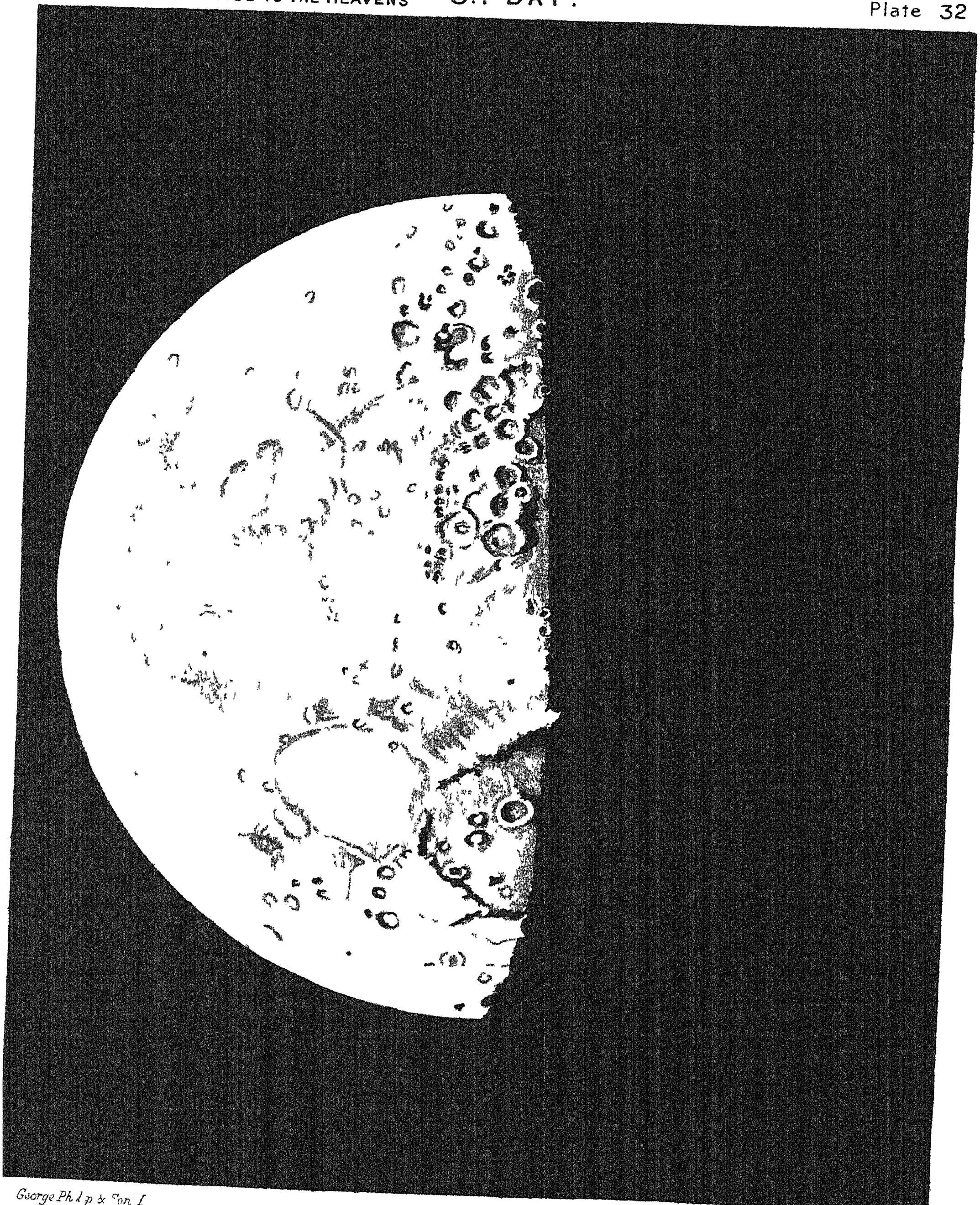
278 *Regiomontanus*
277 *Purbach*
274. *Thebit*
266 *Arzachel*
267 *Alpetragius*
265. *Alphonsus.*
264 *Ptolemæus.*
263 *Herschel.*
261 *Mosting*
373. *Sommering.*
374 *Schroter*
376. *Bode.*
260. *Autolycus.*
399. *Archimedes*
257 *Theætetus.*
259 *Aristillus.*
258 *Cassini.*
211 *Great Alpine Valley*
413 *Plato*
414 *Timæus.*
416 *Epigenes*
417. *Goldschmidt*

P *Sinus Medii.*
M ,, *Æstuum*
J *Mare Serenitatis.*
L ,, *Imbrium*

X *Palus Nebularum*
Z ,, *Putredinis*
K *Mare Frigoris*

a. *The Alps*
b *The Caucasus*
The Apennines

8TH DAY.



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300. *Moretus.*
299. *Cysatus.*
298 *Clavius.*

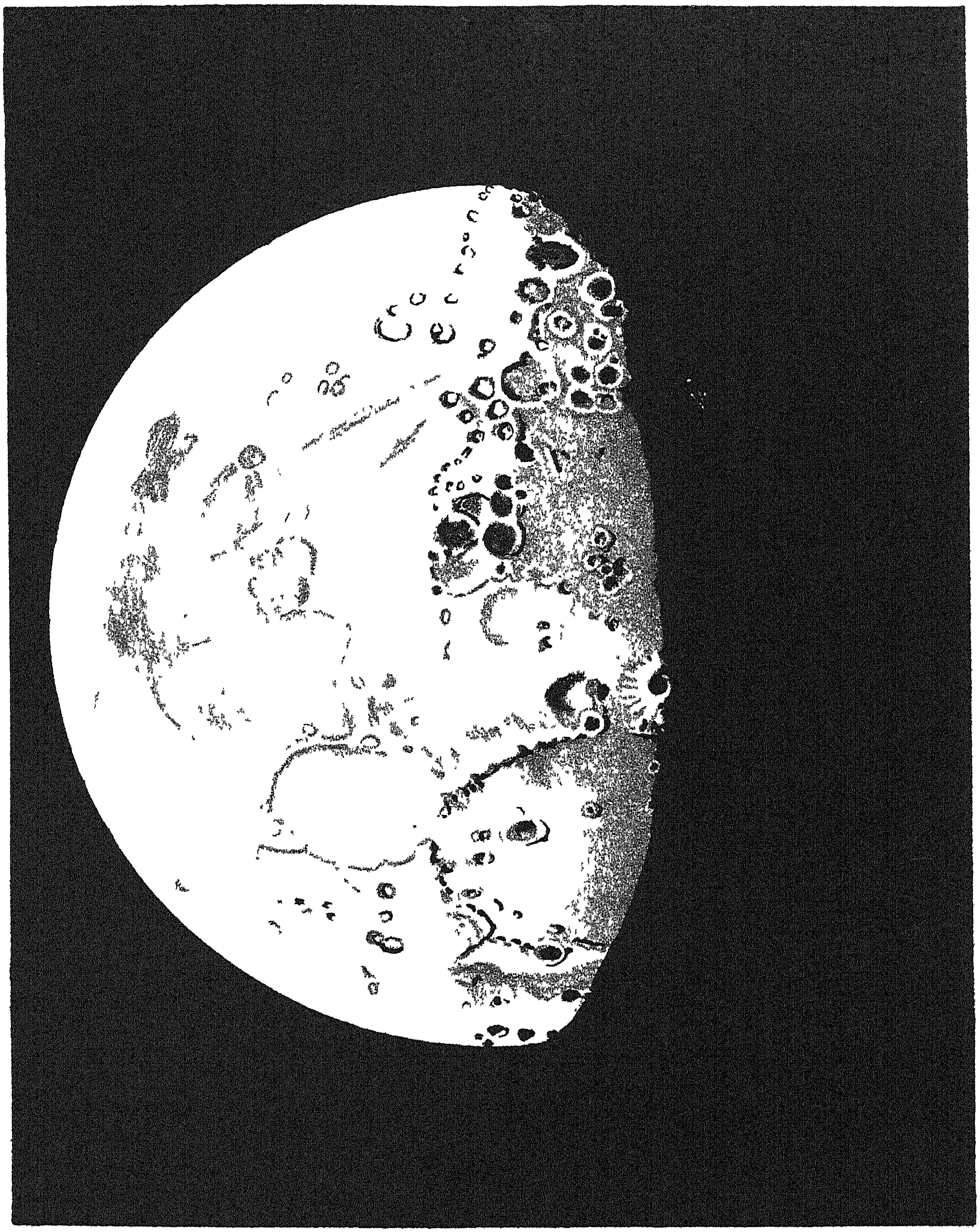
296. *Maginus.*
294. *Longomontanus.*
291. *Tycho.*

293 *Wilhelm*
292 *Heinsius*
282. *Gauricus.*
283 *Wurzelbauer.*
280. *Sasserides.*
281 *Hesiodus.*
275. *Straight Wall.*
344. *Nicollet.*
274 *Thebit*
266. *Arzachel*
267 *Alpetragius*
265. *Alphonsus.*
264 *Ptolemæus.*
270 *Guerike*
271. *Parry.*
272 *Bonpland.*
262. *Lalande.*
273 *Fra Mauro.*
372 *Gambart.*
377 *Reinhold.*
381. *Stadius.*
380. *Copernicus.*
382. *Eratosthenes.*
383. *Gay Lussac.*
403 *Pytheas.*
401. *Timocharis.*
402 *Lambert.*
399. *Archimedes*
413 *Plato*
419. *Fontenelle.*
417. *Goldschmidt.*
418 *Anaxagoras*

K *Mare Frigoris.*
L „ *Imbrium.*
N *Sinus Æstuum*

P *Sinus Medii*
Q *Mare Nubium*

a. *The Alps*
b *The Caucasus Mts.*
c *The Apennines*



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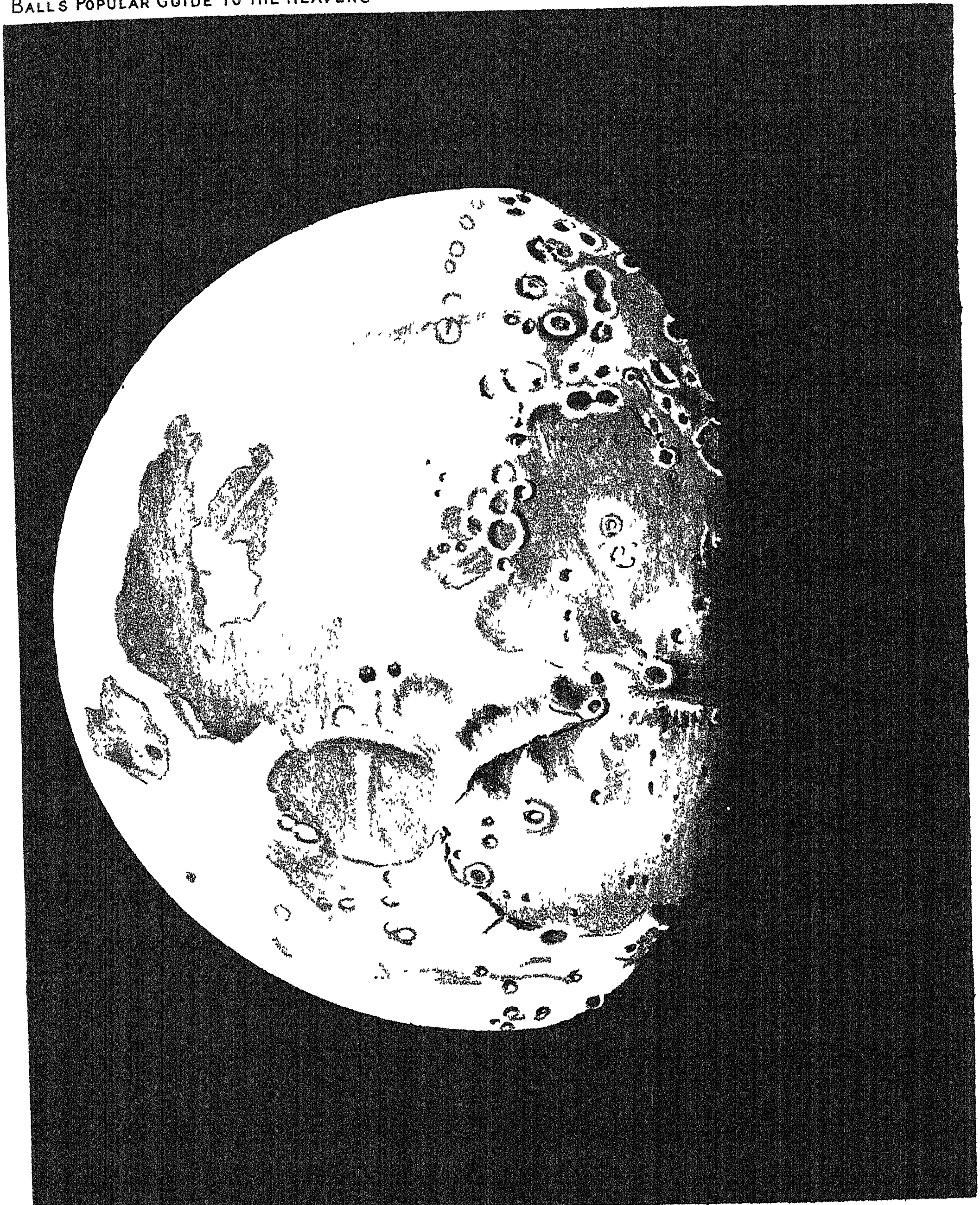
10TH DAY.



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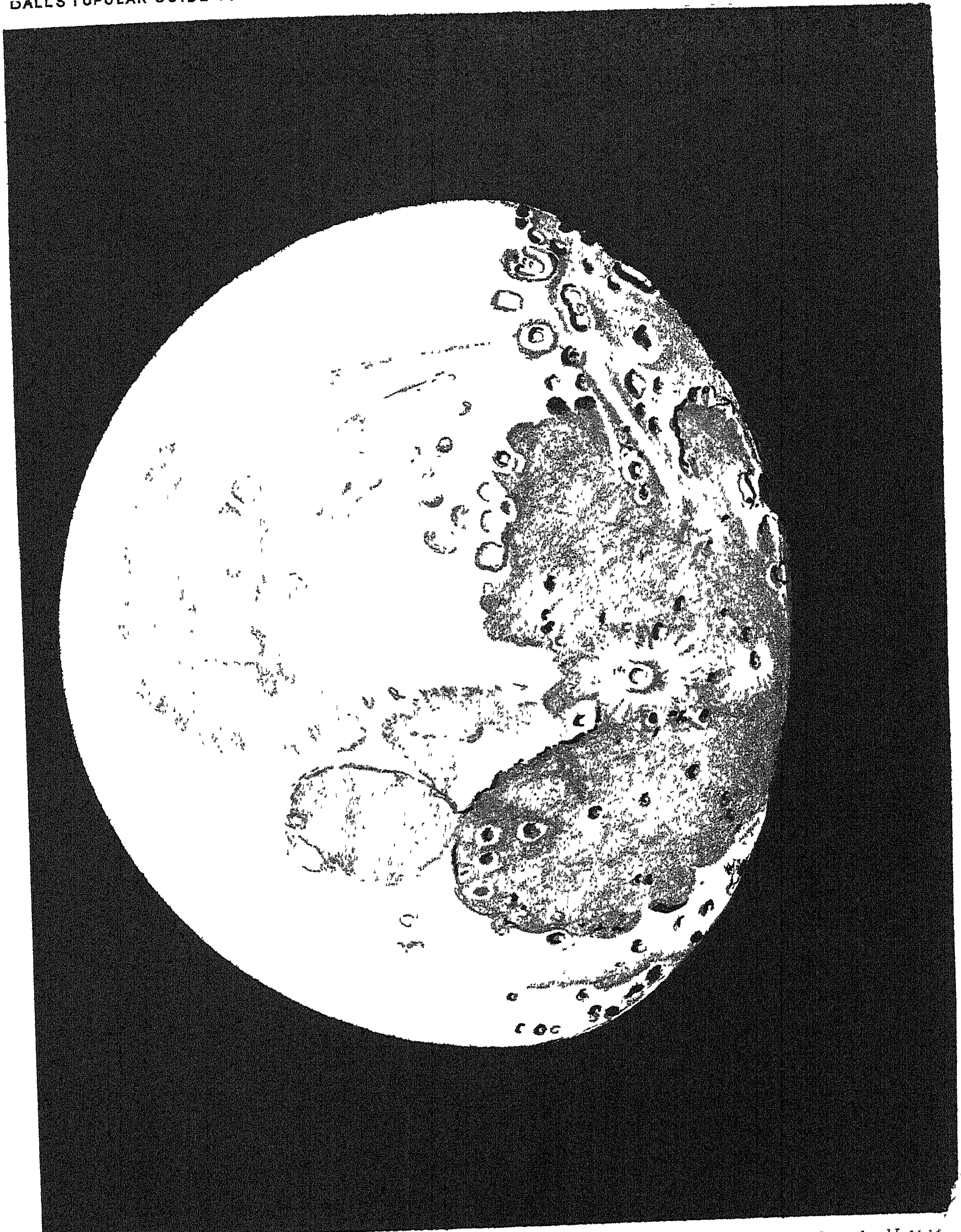
305. *Casatus.*
306 *Klaproth.*
307. *Wilson*

309. *Bettinus*
311 *Segner.*
313. *Scheiner.*

298. *Clavius.*
315. *Rost.*
317. *Schiller.*
318 *Bayer.*
326. *Hainzel.*
337. *Capuanus.*
355. *Ramsden.*
335. *Vitello.*
334. *Lee.*
333. *Doppelmayer.*
345 *Hippalus.*
346 *Agatharchides.*
347 *Gassendi.*
348. *Herigonius.*
349 *Letronne.*
370 *Euclides*
369. *Wichmann.*
368. *Flamsteed.*
371. *Landsberg*
385 *Kunowsky.*
377 *Reinhold.*
386 *Encke.*
378. *Hortensius.*
387 *Kepler.*
380 *Copernicus.*
379. *Milichius*
384 *Tobias Mayer.*
383. *Gay Lussac.*
404 *Euler.*
402 *Lambert.*
401 *Timocharis.*
399. *Archimedes.*
405 *Diophantus*
406. *Delisle.*
451. *Gruithuisen*
427. *Mairan*
426. *Sharp*
425. *Bianchini.*
423 *Condamine.*
413. *Plato*
429. *Harpalus.*
430. *J F. W. Herschel.*
420. *Philolaus.*
421 *Anaximenes*
1. *Riphæan Mts.*
q *Pico.*
r. *Piton Mountain.*
u. *Prom. Laplace.*

L *Mare Imbrium.*
K ,, *Frigoris.*
Q ,, *Nubium.*
R *Sinus Iridum.*
S *Oceanus Procellarum*
T *Mare Humorum.*

a *The Alps*
b *The Caucasus.*
c *The Apennines.*
d. *The Carpathians.*
e. *The Sinus Iridum Highlands.*



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